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TRANSACTIONS
OF
THE FEDERATED INSTITUTION
OF
MINING ENGINEERS.

VOL. V.—1892-93.

EDITED BY M. WALTON BROWN, SECRETARY.

NEWCASTLE-UPON-TYNE: PUBLISHED BY THE INSTITUTION.

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ANY PUBLICATION OF A FEDERATED INSTITUTE MAY BE PLACED AT THE END OF THE VOLUME, *i.e.*, “ANNUAL REPORT,” “LIST OF MEMBERS,” ETC., ETC.

FEDERATED INSTITUTION OF MINING ENGINEERS.

BYE-LAWS

Passed at Council Meeting held on May 28th, 1891.

I.—CONSTITUTION.

1.—The Federated Institution of Mining Engineers shall consist of all or any of the societies interested in the advancement of mining, metallurgy, engineering, and their allied industries, who shall from time to time join together and adhere to the Bye-Laws.

2.—The Institution shall have for its objects—

- (a) The advancement and encouragement of the sciences of mining, metallurgy, engineering, and their allied industries.
- (b) The interchange of opinions, by the reading of communications from members and others, and by discussions at general meetings, upon improvements in mining, metallurgy, engineering, and their allied industries.
- (c) The publication of original communications, discussions, and other papers connected with the objects of the Institution.
- (d) The purchase and disposal of real and personal property for such objects.
- (e) The performance of all things connected with or leading to the purpose of such objects.

3.—The offices of the Institution shall be in Newcastle-upon-Tyne, or such other place as shall be from time to time determined by resolution of the Council.

4.—The year of the Institution shall end on July 31st in every year.

5.—The affairs and business of the Institution shall be managed and controlled by the Council.

II.—MEMBERSHIP.

6.—The original adherents or founders are as follows:—

- (a) Chesterfield and Midland Counties Institution of Engineers, Chesterfield.
- (b) Midland Institute of Mining, Civil, and Mechanical Engineers, Barnsley.
- (c) North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne.
- (d) South Staffordshire and East Worcestershire Institute of Mining Engineers, Birmingham.

7.—Written applications from societies to enter the Institution shall be made to the Council, by the President of the applying society, who shall furnish any information that may be desired by the Council.

8.—A.—If desired by the Council, any of the Federated Institutes shall revise their Bye-Laws, in order that their members shall consist of Ordinary Members, Associate Members, and Honorary Members, with Associates and Students, and section B following shall be a model Bye-Law to be adopted by any society when so desired by the Council.

B.—“The members shall consist of Ordinary Members, Associate Members, and Honorary Members, with Associates and Students :—

- (a) Each Ordinary Member shall be more than twenty-three years of age, have been regularly educated as a mining, metallurgical, or mechanical engineer, or in some other branch of engineering, according to the usual routine of pupilage, and have had subsequent employment for at least two years in some responsible situation as an engineer; or if he has not undergone the usual routine of pupilage, he must have been employed or have practised as an engineer for at least five years.
- (b) Each Associate Member shall be a person connected with or interested in mining, metallurgy, or engineering, and not practising as a mining, metallurgical, or mechanical engineer, or some other branch of engineering.
- (c) Each Honorary Member shall be a person who has distinguished himself by his literary or scientific attainments, or who may have made important communications to any of the Federated Institutes.
- (d) Associates shall be persons acting as under-viewers, under-managers, or in other subordinate positions in mines or metallurgical works, or employed in analogous positions in other branches of engineering.
- (e) Students shall be persons who are qualifying themselves for the profession of mining, metallurgical, or mechanical engineering, or other branch of engineering, and such persons may continue Students until they attain the age of twenty-five years."

9.—The Ordinary Members, Associate Members, and Honorary Members, Associates and Students shall have notice of, and the privilege of attending, the ordinary and annual general meetings, and shall receive all publications of the Institution. They may also have access to, and take part in, the general meetings of any of the Federated Institutes.

10.—The members of any Federated Institute, whose payments to the Institution are in arrear, shall not receive the publications and other privileges of the Institution.

11.—After explanations have been asked by the President from any Federated Institute, whose payments are in arrear, and have not been paid within one month after written application by the Secretary, the Council may decide upon its suspension or expulsion from the Institution; but such suspension or expulsion shall only be decided at a meeting attended by at least two-thirds of the members of the Council by a majority of three-fourths of the members present.

III.—SUBSCRIPTIONS.

12.—Each of the Federated Institutes shall pay fifteen shillings per annum for each Ordinary Member, Associate Member, Honorary Member, Associate, and Student, or such other sum, and in such instalment or instalments as may be determined from time to time by resolution or resolutions of the Council. Persons joining any of the Federated Institutes during the financial year of the Federated Institution shall be entitled to all publications issued for that year, after his election is notified to the Secretary, and the instalment or instalments due on his behalf have been paid.

IV.—ELECTION OF OFFICERS AND COUNCIL.

13.—The officers of the Institution, other than the Secretary and Treasurer, shall consist of Councillors elected annually prior to August in each year, by and out of the Ordinary Members and Associate Members of each Federated Institute, in the proportion of one Councillor per forty Ordinary Members or Associate Members thereof; of Vice-Presidents elected by and from the Council at their first meeting in each year on behalf of each Institute, in the proportion of one

Vice-President per two hundred Ordinary Members or Associate Members thereof ; and of a President elected by and from the Council at their first meeting in each year ; who, with the Local Secretaries of each Federated Institute and the Secretary and Treasurer shall form the Council. All Presidents on retiring from that office shall be *ex-officio* Vice-Presidents so long as they continue Ordinary Members or Associate Members of any of the Federated Institutes.

14.—In case of the decease, expulsion, or resignation of any officer or officers, the Council may, if they deem it requisite, fill up the vacant office or offices at their next meeting.

V.—DUTIES OF OFFICERS AND COUNCIL.

15.—The Council shall represent the Institution and shall act in its name, and shall make such calls upon the Federated Institutes as they may deem necessary, and shall transact all business and examine accounts, authorise payments and may invest or use the funds in such manner as they may from time to time think fit, in accordance with the objects and Bye-Laws of the Institution.

16.—The Council shall decide the question of the admission of any society, and may decree the suspension or expulsion of any Federated Institute for non-payment of subscriptions.

17.—The Council shall decide upon the publication of any communications.

18.—There shall be three ordinary meetings of the Council in each year, on the same day as, but prior to, the ordinary or annual general meetings of the members.

19.—A special meeting of the Council shall be called whenever the President may think fit, or upon a requisition to the Secretary signed by ten or more of its members, or by the President of any of the Federated Institutes. The business transacted at a special meeting of the Council shall be confined to that specified in the notice convening it.

20.—The meetings of the Council shall be called by circular letter, issued to all the members at least seven days previously, accompanied by an agenda paper, stating the nature of the business to be transacted.

21.—The order in which business shall be taken at the ordinary and annual general meetings may be, from time to time, decided by the Council.

22.—The Council may communicate with the Government in cases of contemplated or existing legislation, of a character affecting the interests of mining, metallurgy, engineering, or their allied industries.

23.—The Council may appoint Committees, consisting of members of the Institution, for the purpose of transacting any particular business, or of investigating any specific subject connected with the objects of the Institution.

24.—A Committee shall not have power or control over the funds of the Institution, beyond the amount voted for its use by the Council.

25.—Committees shall report to the Council, who shall act thereon and make use thereof as they may elect.

26.—The President shall take the chair at all meetings of the Institution, the Council, and Committees at which he may be present.

27.—In the absence of the President, it shall be the duty of the senior Vice-President present to preside at the meetings of the Institution. In case of the absence of the President and of all the Vice-Presidents, the meeting may elect any member of Council, or in case of their absence any Ordinary Member or Associate Member to take the chair at the meeting.

28.—At meetings of the Council six shall be a quorum.

29.—Every question shall be decided at the meetings of the Council by the votes of the majority of the members present. In case of equal voting, the President, or other member presiding in his absence, shall have a casting vote. Upon the request of two members, the vote upon any question shall be by ballot.

30.—The Secretary shall be appointed by and shall act under the direction and control of the Council. The duties and salary of the Secretary shall be fixed and varied from time to time at the will of the Council.

31.—The Secretary shall summon and attend all meetings of the Council, and the ordinary and annual general meetings of the Institution, and shall record the proceedings in the minute book. He shall direct the administrative and scientific publications of the Institution. He shall have charge of and conduct all correspondence relative to the business and proceedings of the Institution, and of all committees where necessary, and shall prepare and issue all circulars to the members.

32.—One and the same person may hold the office of Secretary and Treasurer.

33.—The Treasurer shall be appointed annually by the Council at their first meeting in each year. The income of the Institution shall be received by him, and shall be paid into Messrs. Lambton & Co.'s bank at Newcastle-upon-Tyne, or such other bank as may be determined from time to time by the Council.

34.—The Treasurer shall make all payments on behalf of the Institution, by cheques signed by two members of Council, the Treasurer, and the Secretary after payments have been sanctioned by Council.

35.—The surplus funds may, after resolution of the Council, be invested in Government securities, in railway and other debenture shares such as are allowed for investment by trustees, in the purchase of land, or in the purchase, erection, alteration, or furnishing of buildings for the use of the Institution. All investments shall be made in the names of Trustees appointed by the Council.

36.—The accounts of the Treasurer and the financial statement of the Council shall be audited and examined by a chartered accountant, appointed by the Council at their first meeting in each year. The accountants' charges shall be paid out of the funds of the Institution.

37.—The minutes of the Council's proceedings shall at all times be open to the inspection of the Ordinary Members and Associate Members.

VI.—GENERAL MEETINGS.

38.—An ordinary general meeting shall be held in February, May, and September, unless otherwise determined by the Council; and the ordinary general meeting in the month of September shall be the annual general meeting at which a report of the proceedings, and an abstract of the accounts of the previous year ending July 31st, shall be presented by the Council. The ordinary general meeting in the month of May shall be held in London, at which the President may deliver an address.

39.—Invitations may be sent by the Secretary to any person whose presence at discussions shall be thought desirable by the Council, and persons so invited shall be permitted to read papers and take part in the proceedings and discussions.

40.—Discussion may be invited on any paper published by the Institution, at meetings of any of the Federated Institutes, at which the writer of the paper may be invited to attend. Such discussion, however, shall in all cases be submitted to the writer of the paper before publication, and he may append a reply at the end of the discussion.

VII.—PUBLICATIONS.

41.—The publications may comprise:—

- (a) Papers upon the working of mines, metallurgy, engineering, railways and the various allied industries.
- (b) Papers on the management of industrial operations.
- (c) Abstracts of foreign papers upon similar subjects.
- (d) An abstract of the patents relating to mining and metallurgy, etc.
- (e) Notes of questions of law concerning mines, manufactures, railways, etc.

42.—Each paper (with complete drawings, if any, to scale), to be read at any meeting of the Institution or of any of the Federated Institutes shall be placed in the hands of the Secretary at least fourteen days before the date of the meeting at which the paper is to be read, and shall, subject to the approval of the Council, be printed, together with any discussion or remarks thereon.

43.—The Council may accept communications from persons who are not members of the Institution and allow them to be read at the ordinary or annual general meetings.

44.—No paper which has already been published (except as provided for in Bye-Law 41) shall appear in the publications of the Institution.

45.—A paper in course of publication cannot be withdrawn by the writer.

46.—Proofs of all papers and reports of discussions forwarded to any person for revision must be returned to the Secretary within seven days from the date of their receipt, otherwise they will be considered correct and be printed off.

47.—The copyright of all papers accepted for printing by the Council shall become vested in the Institution, and such communications shall not be published for sale or otherwise without the written permission of the Council.

48.—Twenty copies of each paper and the accompanying discussion shall be presented to the writer free of cost. He may also obtain additional copies upon payment of the cost to the Secretary, by an application attached to his paper. These copies must be unaltered copies of the paper as appearing in the publication of the Institution, and the cover shall state that it is an "Excerpt from the Transactions of the Federated Institution of Mining Engineers."

49.—The Federated Institutes may receive copies of their own portion of the publications in respect of such of their members as do not become members of the Federated Institution, and shall pay 10s. per annum in respect of every copy so supplied; and similar copies for exchanges shall be paid for at cost price.

50.—The Local Secretary of each Federated Institute shall prepare and edit all papers and discussions of such Institute, and promptly forward them to the Secretary, who shall submit proofs to the Local Secretary before publication.

51.—A list of the members, with their last known addresses, shall be printed in the publications of the Institution.

52.—The publications of the Institution shall only be supplied to members, and no duplicate copies of any portion of the publications shall be issued to any member or Federated Institute unless by order of the Council.

53.—The annual volume or volumes of the publications may be sold, in the complete form only, at such prices as may be determined from time to time by the Council; to non-members for not less than £3; and to members who are desirous of completing their sets of the publications, for not less than 15s.

54.—The Institution as a body is not responsible for the statements and opinions advanced in the papers which may be read or in the discussions which may take place at the meetings of the Institution, or of the Federated Institutes.

VIII.—MEDALS AND OTHER REWARDS.

55.—The Council may award annually the sum of twenty pounds, in the form of medals or other rewards, to the authors of papers published by the Institution.

IX.—PROPERTY.

56.—The capital fund shall consist of such amounts as shall from time to time be determined by resolution of the Council.

57.—The Institution may make use of the following receipts for its expenses :—

- (a) The interest of its accumulated capital fund ;
- (b) The annual subscriptions ; and
- (c) Receipts of all other descriptions.

58.—The Institution may form a collection of papers, books, and models.

59.—Societies or members who may have ceased their connexion with the Institution shall have no claim to participate in any of its properties.

60.—All donations to the Institution shall be acknowledged in the annual report of the Council.

X.—ALTERATION OF BYE-LAWS.

61.—No alteration shall be made in the Bye-Laws of the Institution, except at a special meeting of the Council called for that purpose, and the particulars of every such alteration shall be announced at their previous meeting, and inserted in the minutes, and shall be sent to all members of Council at least fourteen days previous to such special meeting, and such special meeting shall have power to adopt any modification of such proposed alteration of the Bye-Laws, subject to confirmation by the next ensuing Council meeting.

THE FEDERATED INSTITUTION OF MINING ENGINEERS.

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BURNS, J. B., The Oaklands, Rugeley.
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BUTCHER, WILLIAM, Chesterton, Staffordshire.
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 CARR, ROBERT, Usworth Colliery, Washington, R.S.O.
 CARR, WM. COCHRAN, Benwell Colliery, Newcastle-upon-Tyne.
 CARRINGTON, ARTHUR, Warney Lee, Darley Dale, Matlock Bridge.
 CARRINGTON, T., Kiveton Park Colliery, Sheffield.
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 CHEESMAN, I. T., Throckley Colliery, Newcastle-upon-Tyne.
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 CHILDE, HENRY S., Wakefield.
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 CLARK, W. F., Glenthorn, Holyhead Road, Handsworth, Birmingham.
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 DARLINGTON, JAMES, Black Park Colliery, Ruabon, North Wales.
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 DEAN, FRANK, Railway Foundry, Stoke-upon-Trent.
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 DICKINSON, JOSEPH, South Bank, Pendleton, Manchester.
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 DODD, M., Burncroft, Hexham.
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 EASTWOOD, G. A., Tapton Villa, Chesterfield.
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 EVERARD, J. B., 6, Millstone Lane, Leicester.

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 *FIRTH, W., Water Lane, Leeds.
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 FISHER, T. T., Walsall.
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 FLETCHER, JOHN, Gill House, Ulverstone.
 FLETCHER, LANCELOT, Brigham Hall, Carlisle.
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 FOGGO, W., Brereton Collieries, Rugeley.
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 FROST, WILLIAM, Sneyd Colliery, Burslem, Stoke-upon-Trent.
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FRYAR, MARK, Denby Colliery, Derby.

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GALLOWAY, W., Cardiff.

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GRAZEBROOK, A. W., Queen's Cross, Dudley, Worcestershire.

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 HANN, EDMUND, Aberaman, Aberdare.
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 HARGREAVES, WILLIAM, Rothwell Haigh Colliery, Leeds.
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 HARLE, RICHARD, Browney Colliery, Durham.
 HARLE, WILLIAM, Pagebank Colliery, near Durham.
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 HARRISON, G. B., West Hunwick Colliery, Hunwick, R.S.O., Co. Durham.
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 HARRISON, W. B., Brownhills Collieries, near Walsall.

- HARRUP, J. A., Westminster Collieries, Wrexham.
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 HEDLEY, J. HUNT, John Street, Sunderland.
 *HEDLEY, J. J., Derwent Cote House, Lintz Green Station.
 HEDLEY, SEPT. H., Bank Chambers, Wakefield.
 HEDLEY, W. H., Medomsley, R.S.O., Newcastle-upon-Tyne.
 HENDERSON, C. W. C., The Riding, Hexham.
 HENDERSON, H., Pelton Colliery, Chester-le-Street.
 HENDERSON, J. J., Khewra, Sind Sagar S. Railway, Punjab, India.
 HENDERSON, J. J., U.S. Engineer's Office, Kingsbridge, New York, U.S.A.
 HENDY, J. C. B., Colliery Office, Etherley, by Darlington.
 HENSHAW, A. MAYON, Talk-o'-th'-Hill Colliery, Stoke-upon-Trent.
 HENZELL, ROBERT, Close, Newcastle-upon-Tyne.
 HEPBURN, T., Langley Park, Durham.
 HEPPPELL, T., Leafield House, Birtley, Chester-le-Street.
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 Oaks, Nottingham.
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 HESLINGTON, ALFRED, New Tupton, Chesterfield.
 HESLOP, C., Upleatham and Lingdale Mines, Upleatham, R.S.O., Yorkshire.
 HESLOP, GRAINGER, Deptford Hall, Sunderland.
 HESLOP, JAMES, The Elms, Arnold, Nottingham.
 HESLOP, THOMAS, Storey Lodge Colliery, Cockfield, *via* Darlington.
 HETTON COAL COMPANY, Fence Houses.
 HEWITT, C. R., London Road, Derby.
 HEWITT, GEORGE, Castle Gresley, Burton-upon-Trent.
 HEWITT, G. C., Coal Pit Heath Colliery, near Bristol.
 HEWITT, H. R., H.M. Inspector of Mines, 47, Hartington Street, Derby.
 HEWITT, JOHN RICHARDSON, Derby.
 HEWITT, JOSEPH, Heron Cross, Fenton, Stoke-upon-Trent.
 HEWITT, T. P., Swadlincote and Cadley Hill Collieries, Burton-upon-Trent.
 HEWLETT, A., Haseley Manor, Warwick.

- HICKMAN, E., Stone Quarries, Bilston.
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 HILL, WILLIAM, Carterthorne Colliery Offices, Witton-le-Wear.
 HILL, WILLIAM, Manor Street Foundry, Fenton, Stoke-upon-Trent.
 HILTON, J., 67, Hawkshead Street, Southport.
 HILTON, T. W., Wigan Coal and Iron Co., Limited Wigan.
 HINCHLIFFE, J., Bullhouse Colliery, Penistone, near Sheffield.
 HIRST, G. F., Aldwarke Main Colliery, Rotherham.
 HOBBS, WILLIAM L., Whitfield Collieries, Norton-in-the-Moors, Stoke-upon-Trent.
 HODGES, ISAAC, Sheepbridge Works, Chesterfield.
 HODGKINSON, ALBERT, The Laurels, Wollaton, Nottingham.
 HODGSON, E., Black Boy Colliery, Bishop Auckland.
 HODGSON, J., Edmondsley Colliery, Chester-le-Street.
 HODSON, JAMES, Brintirion, Prestatyn, North Wales.
 HODSON, JAMES E., Belgrave Terrace, Normacot, Longton, Staffordshire.
 HOLBROOK, JOHN, Langley Colliery, Marpool, Derby.
 HOLDING, WILLIAM, Cossall Colliery, Nottingham.
 HOLDSWORTH, THOMAS, Clay Cross, Chesterfield.
 HOLFORD, W. D., Whittington, Chesterfield.
 HOLLIDAY, MARTIN F., Langley Grove, Durham.
 HOLLIDAY, ROSLYN, Featherstone Manor Colliery, Pontefract.
 HOLLIDAY, T., West Ardsley Collieries, Tingley, near Wakefield.
 HOLLINS, G., High Street, Wolstanton, Stoke-upon-Trent.
 HOLLIS, HENRY WM., Whitworth House, Spennymoor.
 HOLMES, C., Grange Hill, near Bishop Auckland.
 *HOMER, CHARLES J., Stoke-upon-Trent.
 HOMER, J. EDWARD, Ivy House, Hanley, Stoke-upon-Trent.
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 HOPKINSON, HENRY, Station Street, Nottingham.
 HOPKINSON, JOHN, Inglewood, St. Margaret's Road, Bowden, Cheshire.
 HOPPER, J. L., Tyne Dock, South Shields.
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 HOUFTON, J. P., Bolsover Colliery, Chesterfield.
 HOULGATE, J. KERR, 69, Lowther Street, Whitehaven.
 HOWARD, W. F., 15, Cavendish Street, Chesterfield.
 HOWDEN, THOMAS, Wakefield.
 HOWE, WM., Clay Cross, Chesterfield.
 HOWES, FRANK T., Singareni Collieries, Hyderabad Deccan Co., Secunderabad,
 India.
 HOWL, E., The Quarries Dudley, Worcestershire.
 HUBBERSTY, H. A., Burbage, Buxton.
 HUGHES, H. W., Priory Farm House, Dudley, Worcestershire.

HUGHES, JAMES, Midland Coal and Iron Co., Minnie Pit, Halmerend, Newcastle, Staffordshire.

HUGHES, J., Dudley, Worcestershire.

HUGHES, THOMAS GEORGE, Blackwell, Alfreton.

HUGHES, WILLIAM, Springwood, Chesterton, Staffordshire.

HULSE, W. W., Longton Gas Works, Longton, Staffordshire.

HUMBLE, JOSEPH, Markham Collieries, Duckmanton, Chesterfield.

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HUNTER, CHRISTOPHER, Broomhill Colliery, Acklington, Northumberland.

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HUTTON HENRY COAL COMPANY, LIMITED, 7, Bondgate, Darlington.

HYSLOP, G. P., Mossfield Colliery, Longton, Staffordshire.

IRVINE, JOSEPH R., Hendon Ropery, Sunderland.

JACKSON, ALFRED, Park Hall Collieries, near Longton, Staffordshire.

JACKSON, ANDREW, Collins Green Collieries, Newton-le-Willows, Lancashire.

JACKSON, JOHN, Stubben Edge, Chesterfield.

JACKSON, W. B. M., Clay Cross Hall, Chesterfield.

JACKSON, W. G., Hicklam House, Aberford, near Leeds.

JARRATT, J., Houghton Main Colliery, Barnsley.

JEFFCOCK, C. E., Birley Collieries, Sheffield.

JEFFCOCK, T. W., 18, Bank Street, Sheffield.

JENKINS, W., Ocean Collieries, Treorky, Glamorganshire.

JENKINS, WM., Consett Iron Works, Consett, Durham.

JEPSON, H., 20, The Avenue, Durham.

JEPSON, W. W., Portland Colliery, Selston, Alfreton.

JEUDWINE, W. W., Walton Lodge, Chesterfield.

JOBLING, T. E., Croft Villa, Blyth, Northumberland.

JOHNSON, J., Carlton Main Colliery, Barnsley.

JOHNSON, M. G., Talk-o'-th'-Hill Colliery, Talke, Stoke-upon-Trent.

JOHNSON, W., Abram Colliery, Wigan.

JOHNSON, WM., Framwellgate Moor, Durham.

JOHNSON, WM., Radcliffe Colliery, Acklington, Northumberland.

JOICEY, J. G., Forth Banks West Factory, Newcastle-upon-Tyne.

JOICEY, JAMES JOHN, Sunningdale Park, Berks.

JOICEY, W. J., Sunningdale Park, Berks.

JONES, D. L., Shelton Steel Co., Stoke-upon-Trent.

JONES, F. J., Rother Vale Collieries, Treeton, Rotherham

JONES, GEORGE, The Hall, Bloxwich.

JONES, JOHN, Shire Oaks Colliery, Worksop.

JONES, J. A., Gijon, Asturias, Spain.

JONES, JACOB CARLOS, Bellambi, New South Wales.

JONES, LLOYD, Ruabon, North Wales.

JONES, R. ENOS, Whitwell Colliery, Whitwell, Chesterfield.

JONES, THOMAS E., Shelton Bar Ironworks, Stoke-upon-Trent.

KAYLL, A. C., Gosforth, Newcastle-upon-Tyne.

KEEP, R. S., Messrs. Horsley and Co., Tipton, Staffordshire.

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KELLETT, WILLIAM, Portland Bank, Southport.

- KENDALL, J. D.**, Foxhouses Road, Whitehaven.
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KENT, GEORGE C., Longton, Staffordshire.
KESTEVEN, FRANK, Monckton Main Colliery, Barnsley.
KIDSON, E, Lester Street, Bilston.
KING, FRED., Cramlington Colliery, R.S.O., Northumberland.
KIRKBY, J. W., Kirkland, Leven, Fife.
KIRKUP, AUSTIN, Murton Colliery, Sunderland.
KIRKUP, FRED. O., Hutton Henry Colliery, Wingate, R.S.O., Co. Durham.
KIRKUP, J. P., 5, Albert Edward Terrace, Whitley.
KIRKUP, PHILIP, Cornsay Colliery Office, Esh, near Durham.
KIRTON, HUGH, Kimblesworth Colliery, Chester-le-Street.
KNIGHTON, HERBERT, High Park Colliery, Greasley, Notts.
KNIGHTON, H. A., Bagworth, Leicester.
KNOWLES, JOHN, Westwood, Pendlebury, Manchester.
KNOWLES, ROBERT, Ednaston Lodge, near Derby.

LAKE, The Very Rev. Dr., Dean of Durham.
LAKE, GEORGE, Penkhull, Stoke-upon-Trent.
LAMB, GEORGE, Butterley Park Collieries, Alfreton.
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LANCASTER, JOHN, Heathfield, Lesmahagow, N.B.
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LAVERICK, J. H. W., Riddings Colliery, near Alfreton.
LAVERICK, JAS., East Gawber Colliery, Barnsley.
LAVERICK, JOHN WALES, Tow Law Colliery Office, Tow Law, R.S.O., Co. Durham.

LAVERICK, ROBT., West Rainton, Fence Houses.
LAWLEY, J., Cradley Heath, Staffordshire.
LAWRENCE, H., Grange Iron Works, Durham.
LAWRENCE, H. L., 3, Maxilla Gardens, North Kensington, London, W.
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LEE, JOHN F., Sheepbridge Iron Works, Chesterfield.
LEES, T. G., Clifton Colliery, Nottingham.
LEWIS, GEORGE, Imperial Chambers, Albert Street, Derby.
LEWIS, HENRY, Annesley Colliery, Nottingham.
LEWIS, Sir WILLIAM THOMAS, Mardy, Aberdare.
LIDDELL, J. M., 3, Victoria Villas, Newcastle-upon-Tyne.
LINDAY, JAMES, Bishop Auckland.
LINDLEY, EDWARD, Eastwood, Nottingham.

- LINDOP, J., Lime Tree House, Blorwich, Walsall.
 LINSLEY, R., Cramlington Colliery, Northumberland.
 LINSLEY, S. W., Whitburn Colliery, South Shields.
 LISHMAN, R. R., Durham Main Colliery, Durham.
 LISHMAN, T., Hetton Colliery, Hetton-le-Hole, R.S.O.
 LISHMAN, Wm., Bunker Hill, Fence Houses.
 LISHMAN, Wm., Holly House, Witton-le-Wear.
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 LOGAN, WILLIAM, Langley Park Colliery, Durham.
 LONDONDERRY, MARQUESS OF, c/o V. W. Corbett, Londonderry Offices, Seaham
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 LONGBOTHAM, R. H., 15, Westgate, Wakefield.
 LONGDEN, J. A., Stanton-by-Dale, Nottingham.
 LONGRIDGE, J., Coxlodge Colliery, Newcastle-upon-Tyne.
 LONGRIDGE, J. A., Grève d'Ayette, Jersey.
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 LUCAS, SAMUEL, Dronfield Foundry, Dronfield, Sheffield.
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 LYON, J. W., The Firs, Annesley, Nottingham.
- MACALPINE, G. W., Altham and Great Harwood Collieries, near Accrington.
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 MCGOWAN, JOHN, Harecastle and Woodshutts Collieries, Stoke-upon-Trent.
 MCGOWAN, JOHN, JUN., Harecastle and Woodshutts Collieries, Stoke-upon-Trent.
 MACINTOSH, T., Waterloo, Blyth.
 MACKINLAY, E., East Stanley Colliery, Co. Durham.
 McLAREN, B., Heddon Coal and Fire Brick Co., Wylam-upon-Tyne.
 McMURTRIE, G. E. J., Foxes Bridge Colliery, Cinderford, Gloucestershire.
 McMURTRIE, J., Radstock Colliery, Bath.
 MADDISON, THOS. R., Dirtcar House, near Wakefield.

- MADDISON, W. H. F., The Lindens, Darlington.
 MAKEPEACE, H. R., H.M. Inspector of Mines, Newcastle, Staffordshire.
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 MALING, C. T., Ellison Place, Newcastle-upon-Tyne.
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 MANN, ENOCH, Blakeley House, Dilhorne, Stoke-upon-Trent.
 MARKHAM, C. P., Broad Oaks Iron Works, Chesterfield.
 MARKHAM, G. E., Coundon, Bishop Auckland.
 MARLEY, J. W., Thornfield, Darlington.
 MARRIOTT, JOSEPH, Jun., Acres, Pilsley, Chesterfield.
 MARSH, F. S., Freasley, near Tamworth.
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 MARSHALL, J. L., Monk Bretton Colliery, Barnsley.
 MARSHALL, W., Liversedge Colliery, Liversedge, *via* Normanton.
 MARSHALL, W. B., Richmond Hill, Edgbaston, Birmingham.
 MARTEN, E. B., Pedmore, near Stourbridge.
 MARTIN, C. W., Murton Colliery, *via* Sunderland.
 MARTIN, GILSON, Edensor, Chesterfield.
 MARTIN, R. F., Mountsorrel, Loughborough.
 MARTIN, TOM PATTINSON, Allhallows Colliery, Mealsgate, Carlisle.
 MASCALL, W. H., c/o Mrs. Race, South Church, near Bishop Auckland.
 MASON, BENJ., Burnopfield, R.S.O., Durham.
 MATHIESON, ALEXANDER, Hetton Colliery, Carrington, near Newcastle, New South Wales.
 MATTHEWS, J., Messrs. R. and W. Hawthorn, Newcastle-upon-Tyne.
 MATTHEWS, R. F., Harehope Hall, Alnwick.
 MAUGHAN, J. A., Government Central Provinces Collieries, Umaria, *via* Katni, India, C.P.
 MAWSON, R. BRYHAM, Brick House, Westleigh, Manchester.
 MAY, G., Harton Colliery Offices, near South Shields.
 MAY, T. H., Dronfield, Sheffield.
 MAYDEW, BENJ., Lymie House, Whiston, Prescott.
 MAYES, G. R., Dukinfield Collieries, Dukinfield, near Manchester.
 MEACHEM, F. G., Hillside Cottage, Hamstead Hill, Handsworth, Birmingham.
 MEACHEM, ISAAC, Jun., Batmans Hill House, Bradley, Bilston.
 MEIN, JAMES, South Normanton Colliery, Alfreton.
 MELLING, WM., South Leicestershire Colliery, Coalville, Leicestershire.
 MELLO, Rev. J. M., Mapperley Vicarage, near Derby.
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 MERIVALE, W., The Deanery, Ely.
 MEYER, G. A., Shamrock Collieries, Westphalia.
 MEYSEY-THOMPSON, A. H., Sun Foundry, Leeds.
 MIDDLETON, FRANCIS ED., Lofthouse, Wakefield.
 MIDDLETON, ROBERT, Sheep Scar Foundry, Leeds.
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MITCHELL, JOHN, Swaithe Hall, Barnsley.
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MITCHESON, HARRY, Dresden, Longton, Staffordshire.
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MITTON, A. DURY, Marlpool House, near Derby.
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MOORE, R. W., Somerset House, Whitehaven.
MOORE, WILLIAM, Loftus Mines, Loftus-in-Cleveland, R.S.O.
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MORGAN, THOMAS, Birch Coppice Colliery, near Tamworth.
MORISON, JOHN, Newbattle Collieries, Dalkeith, N.B.
MORRIS, W., Walldridge Colliery, Chester-le-Street.
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MOSBY, GEORGE, Eckington Collieries, Rotherham.
MOSS, HENRY, 223, Derby Road, Nottingham.
MOULD, ENOCH, White Barn Colliery, Newcastle, Staffordshire.
MOULTON, LEVI, Chesterton, Stoke-upon-Trent.
MOUNTAIN, WILLIAM C., Forth Banks, Newcastle-upon-Tyne.
MUIRHEAD, JAMES, Grove Road, Fenton, Stoke-upon-Trent.
MULHOLLAND, M. L., West Cornforth, R.S.O., Co. Durham.
MUNDLE, ARTHUR, St. Nicholas' Chambers, Newcastle-upon-Tyne.
MUNRO, DONALD, Fairfield, Manchester.
MUNROE, Prof. H. S., School of Mines, Columbia College, New York City, U.S.A.
MURTON, CHAS. J., Delaval Benwell Colliery, Newcastle-upon-Tyne.
MUSCHAMP, PERCIVAL, Warren Grove, Sheffield Road, Barnsley.
MUSGRAVE, HENRY, Havercroft Main Colliery, Royston, near Barnsley.
MYATT, JACOB, Newcapel, Tunstall, Staffordshire.
- NASH, H. B., Clarke's Old Silkstone Colliery, Barnsley.
NASSE, RUDOLPH, Geheimerberggrat, Dornsbergstrasse, 6, Berlin, W., Germany.
NAYLOR, JOHN, Cotes Park Colliery, near Alfreton.
NEVIN, JOHN, Littlemoor House, Mirfield.
NEWBOULD, T., Low Stubbin Colliery, Rawmarsh, Rotherham.
NEWBY, J. W., Wellington Road, Dudley, Worcestershire.
NEWTON, JAMES, Whitehaven Colliery, Whitehaven.
NEWTON, JOHN, Longport, Stoke-upon-Trent.
NICHOL, WM., De Beers Mine, Kimberley, South Africa.
NICHOLSON, A. D., Lane Ends, Hetton-le-Hole, R.S.O., Co. Durham.
NICHOLSON, J. H., Cowpen Colliery Office, Blyth, Northumberland.
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- NICHOLSON, MARSHALL, Middleton Colliery, Leeds.
 NIXON, JOHN, Stafford Coal and Iron Co., Stoke-upon-Trent.
 NOBLE, THOMAS GEORGE, Sacriston Colliery, Durham.
 NORTH, F. W., Rowley Hall Colliery, Dudley, Staffordshire.
 NORTH BRANCEPETH COAL Co., LIMITED, Crown Street Chambers, Darlington.
 NORTH HETTON COLLIERY, OWNERS OF, Fence Houses.
 NOWELL, WILLIAM, Haunchwood Colliery, Nuneaton.

 OAKES, C. H., Holly Hurst, Alfreton.
 OATES, ROBERT J. W., Rajdoha Mining Co., Limited, via Kandra P.O., Bengal
 Nagpur Railway, Bengal, India.
 OATTE, STEPHEN, Cheadle Park Colliery, Cheadle, Staffordshire.
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 ORMEROD, EDWARD, Atherton, Manchester.
 ORNSBY, R. E., Seaton Delaval Colliery, Newcastle-upon-Tyne.
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 OVEREND, JAMES, Mining Offices, Barnsley.
 OWEN, WILLIAM, Bucknall, Stoke-upon-Trent.
 OXLEY, JOSHUA, Wombwell Main Colliery, Barnsley.

 PAGE, F. W., Blackwell Collieries, Alfreton.
 PALMER, A. S., Highfield House, Gateshead-upon-Tyne.
 PALMER, C. B., Usworth Colliery, Washington, R.S.O.
 PALMER, SIR CHAS. MARK, Bart., M.P., Quay, Newcastle-upon-Tyne.
 PALMER, HENRY, East Howle Colliery, near Ferryhill.
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 PANTON, F. S., Silksworth Colliery, Sunderland.
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 PARKIN, J., Rylands Main Colliery, Barnsley.
 PARKIN, L. C., Rylands Main Colliery, Barnsley.
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 PARRY, D. E., Norton Cannock Colliery, Bloxwich, Walsall.
 PARRY, EVAN, Wharnccliffe Woodmoor Colliery, Barnsley.
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 PATTERSON, THOMAS, Craghead, Chester-le-Street.
 PATTERSON, WM., Front Street, Tynemouth.
 PATTISON, WM., Morley Main Colliery, Morley, near Leeds.
 PAYTON, EDMUND, Yew Tree House, Morleston Street, Derby.
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 PEACOCK, W. F., Horsley Collieries, Tipton.
 PEAKE, H. C., Walsall Wood Colliery, Walsall.

- FRANKS, JOHN SAMUEL**, Tinsdale, Northumberland.
FRANKS, E. C., Commercial House, Rotherham, Essex.
FRANKS, ROBERT, York Colliery, Chester, Northumberland.
FRANKS, JAMES, Wharfedale, Chester.
FRANKS, JAMES, The East House, Warrington, Cheshire.
FRANKS, JAMES, Huddersfield, Amberg, Lancashire.
FRANKS, JOHN, Huddersfield.
FRANKS, J. W., York, M.P., Huddersfield, Yorkshire.
FRANKS, W. G., Leyland, Warwickshire.
FRANKS, JOHN, Clara Vale, Ely, Northumberland.
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FRANKS, WILLIAM, Great Hall, Middlesbrough, Whitehaven.
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 WALKER, W. E., Dudley, Worcestershire.
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 WARRINGTON, JAMES HENRY, Berry Hill Works, Stoke-upon-Trent.
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 WEARMOUTH COLLIERY, OWNERS OF, Sunderland.
 WEBSTER, H. INGHAM, Morton House, Fence Houses.
 WEEKS, J. G., Bedlington, R.S.O., Northumberland.
 WEEKS, R. L., Willington, Co. Durham.
 WRIGHTMAN, PERCY O., Garforth Collieries, near Leeds.
 WELLS, W. E., Eckington Collieries, Rotherham.
 WESTMACOTT, P. G. B., Elswick Ironworks, Newcastle-upon-Tyne.
 WESTPORT COAL CO., LIMITED, Manager, Dunedin, New Zealand.
 WHEATLEY, SAMUEL, Nailstone Colliery, Leicester.
 WHEATLY, SAMUEL W., Butterton, Newcastle, Staffordshire.

- WHITE, C. E., Hebburn Colliery, Hebburn-upon-Tyne.
 WHITE, H., Walker Colliery, Newcastle-upon-Tyne.
 WHITE, I. W. H., Woodlesford, near Leeds.
 WHITE, J. F., Westgate, Wakefield.
 WHITE, J. H. R., The Elms, Thringstone, Coalville, Leicester.
 WHITEHEAD, JAMES, Brindle Lodge, near Preston, Lancashire.
 WHITEHEAD, JOHN, Jun., Penworthan Priory, Preston.
 WHITEHEAD, JOHN JAMES, Arden Lea, Heaton, near Bolton, Lancashire.
 WHITEHOUSE, JAMES, Burnt Tree, Tipton, Staffordshire.
 WHITEHOUSE, W. H., Brownhills, Walsall.
 WHITELAW, JOHN, 118, George Street, Edinburgh.
 WHITTEM, THOMAS S., Wyken Colliery, near Coventry.
 WIDDAS, C., North Bitchburn Colliery, Howden, Darlington.
 WIGHT, EDWD. S., Hetton Colliery, Carrington, near Newcastle, New South Wales.
 WIGHT, W. H., Cowpen Colliery, Blyth.
 WILBRAHAM, AARON, Mexboro' Colliery, Selstone, Alfreton.
 WILDE, WILLIAM, Brockett House, Sharrow, Sheffield.
 WILKES, JOHN, Pelsall Foundry, Walsall, Staffordshire.
 WILKINSON, HORACE, Blackwell Collieries, Alfreton.
 WILKINSON, J. R., Spark Lane, Mapplewell, Barnsley.
 WILKINSON, THOMAS, Tinsley, near Sheffield.
 WILLIAMS, EDMUND W., Henshall House, Goldenhill, Stoke-upon-Trent.
 WILLIAMS, ERNEST, P.O. Box 965, Bettelheim Buildings, Simmonds Street, Johannesburg, Z.A.R.
 WILLIAMS, HERBERT IGNATIUS, Alsager, Stoke-upon-Trent.
 WILLIAMS, J., 115, Wellington Road, Dudley, Worcestershire.
 WILLIAMSON, J., Cannock and Rugeley Collieries, Hednesford, Staffordshire.
 WILLIAMSON, J. H., Henshall House, Goldenhill, Stoke-upon-Trent.
 WILLIAMSON, J. T., Brownhills Colliery, Walsall.
 WILLIAMSON, R., Park Hill Colliery, Wakefield.
 WILLIAMSON, R. S., Cannock and Rugeley Collieries, Hednesford, Staffordshire.
 WILLIAMSON, THOMAS, West Hallam Collieries, Ilkeston.
 WILLIS, HENRY STEVENSON, Sacriston, Durham.
 WILSON, A. P., Mansion House Chambers, Queen Victoria Street, London, E.C.
 WILSON, BENJAMIN, Florence Colliery, Longton, Staffordshire.
 WILSON, JACOB, Hucknall Huthwaite, Mansfield.
 WILSON, J. B., Wingfield Iron Works and Colliery, Alfreton.
 WILSON, J. D., Ouston House, Chester-le-Street.
 WILSON, JOHN ROBINSON, H.M. Inspector of Mines, Leeds.
 WILSON, JOSH. M., St. John's Colliery, Normanton.
 WILSON, ROBERT, Flimby Colliery, Maryport.
 WILSON, R. G., Pelton Colliery, Chester-le-Street.
 WILSON, W. B., Thornley Colliery, by Trimdon Grange, Co. Durham.
 WILSON, W. E. C., Snibston Collieries, Coalville, near Leicester.
 WINSTANLEY, PETER, Shaw Cross Colliery, near Dewsbury.
 WINSTANLEY, ROBT., 28, Deansgate, Manchester.
 WINTER, T. B., Grey Street, Newcastle-upon-Tyne.
 WINTERBOTTOM, W., Teversal, Mansfield.
 *WITHERS, SAMUEL, 26, Westgate, Mansfield.

- WITTY, H. SYKES, Denaby Main Colliery, Mexboro', near Rotherham.
 WOISTENHOLME, M., Bestwood Park, Bulwell, Notts.
 WOOD, C. L., Freeland, Forgandenny, Perthshire.
 WOOD, ERNEST SEYMOUR, South Hetton, Sunderland.
 WOOD, JOHN, Coxhoe Hall, Coxhoe, R.S.O., Co. Durham.
 WOOD, LINDSAY, The Hermitage, Chester-le-Street.
 WOOD, THOMAS, North Hetton Colliery Office, Moorsley, Hetton-le-Hole, R.S.O.
 WOOD, T. P., Market Place, Chesterfield.
 WOOD, W. H., Coxhoe Hall, Coxhoe, Co. Durham.
 WOOD, W. O., South Hetton, Sunderland.
 WOODHEAD, ALF., Low Moor Ironworks, Bradford.
 WOODHEAD, L., Beeston Colliery, Leeds.
 WOODS, RICHARD, Jessop Street, Codnor, Derby.
 WOODWORTH, BENJAMIN, Heron Cross, Fenton, Stoke-upon-Trent.
 WOOLLISCROFT, FREDERICK, St. Peter's Chambers, Stoke-upon-Trent.
 WORDSWORTH, ROBERT, Warora Colliery, Central Provinces, India.
 WORDSWORTH, T. H., West Riding Collieries, Normanton.
 WORMALD, C. F., Mayfield Villa, Saltwell, Gateshead-upon-Tyne.
 WORTH, F. G., British Water Gas Syndicate, Park Row, Leeds.
 *WORTHINGTON, JAMES, 11, Foley Place, Fenton, Stoke-upon-Trent.
 WRAY, C., 50, Grantham Road, Bradford.
 WRIGHT, FITZ-HERBERT, The Hayes, Swanwick, Alfreton.
 WRIGHT, JOSEPH, Arboretum Street, Nottingham.
 WRIGHTSON, T., Stockton-upon-Tees.
 WROE, JAMES, Lidgett Colliery, Tankersley, Barnsley.
 WROE, JONATHAN, Wharnccliffe Silkstone Colliery, Barnsley.
 WYNNE, R. H., 19, Marsh Road, Newcastle, Staffordshire.
 WYNNE, T. TRAFFORD.

 YATES, JOHN, c/o MacMillan, 6, Church Lane, Calcutta, India.
 YEOMAN, T., Willington Colliery, Co. Durham.
 YOUNG, JOHN A., 7, Tyne Vale Terrace, Gateshead-upon-Tyne.

 ZUMBULOGLON, G. C., 3. Astartji han, Grand Bazaar, Constantinople.

Non-Federated.

- ARMSTRONG, Prof. G. F., The University, Edinburgh.
 BLAIKIE, JOHN, White Barn Colliery, Newcastle-under-Lyme.
 BULL, JAMES, Cliffe Vale Ironworks, Stoke-upon-Trent.
 CLIVE, ROBERT C., Clanway Colliery, Tunstall, Staffordshire.
 FREEMAN, T., Jun., 200, Phoenix Street, St. Pancras Station, London, N.W.
 GREEN, Prof. A. H., 137, Woodstock Road, Oxford.
 HAYES, WILLIAM PRIME, St. Mary's Place, Bury.
 HOLLIS, H. W., Thornville House, Darlington.
 HOMER, C. J., Ivy House, Stoke-upon-Trent.
 LONGBOTTOM, L., Stoke-upon-Trent.
 LUCAS, JAMES, Shelton Collieries, Stoke-upon-Trent.

MIALI, Prof. L. C., Yorkshire College, Leeds.

OSBORNE, CHARLES, 72, Piccadilly, Hanley, Staffordshire.

PLATT, SAMUEL R., Oldham.

RUCKER, Prof. ERRINGTON, Clapham Park, London.

RUSSELL, R., Sea View, St. Bees, Carnforth.

THORPE, Prof. T. E., Science and Art Department, South Kensington,
London, S.W.

TRELOVON, C. H., 2, St. John's Place, Wretham Road, Handsworth.

WOODALL, WILLIAM, Bleak House, Burslem, Stoke-upon-Trent.

TRANSACTIONS
OF THE
FEDERATED INSTITUTION
OF
MINING ENGINEERS.

FEDERATED INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,

HELD IN THE ROOMS OF THE INSTITUTION OF CIVIL ENGINEERS, 25, GREAT
GEORGE STREET, WESTMINSTER, THURSDAY, JUNE 1ST, 1893.

MR. GEORGE LEWIS, PRESIDENT, IN THE CHAIR.

PRIZES.

The SECRETARY announced that the President's prize of books had been awarded for the paper on

"Mining in New Zealand." By Mr. G. J. Binns.

The SECRETARY further announced that the Council had awarded prizes of books to the writers of the following papers:—

"Observations on Petroleum in Eastern Europe, and the Method of Drilling for it." By Mr. A. W. Eastlake.

"A General Description of the South Staffordshire Coal-field, south of the Bentley Fault, and the Methods of Working the Ten yard or Thick Coal." By Messrs. W. F. Clark and H. W. Hughes.

"An Enquiry into the Cause of the Two Seaham Explosions, 1871 and 1880, and the Pochin Explosion, 1884." By Mr. T. H. M. Stratton.

The PRESIDENT then read his address, as follows:—

PRESIDENTIAL ADDRESS

BY MR. GEORGE LEWIS.

Following the precedent of previous years when your Presidents have addressed you, it is with pleasure that I purpose following in their footsteps; presuming that I may hope, to some extent, to be able to interest you.

The gentlemen who have preceded me in the office of President are well known as having gained their position by being men of sound judgment and ability; and I fully appreciate the great honour of being associated with them in the office to which you have been good enough to elect me.

The federation of the mining institutes of this country is only yet in its infancy, but we have had during the three years of its life, proof of its desirability in every stage of its progress. It fully bears out the adage of "unity is strength," even to a greater extent than we could possibly have supposed; and, looking forward to the future, the time does not appear to me far distant when every local institution of the country will have seen the desirability of union, and become federated with us. There is every reason why this should be so; and we may point with pardonable pride in support of this to our publications. I venture to say that never in the history of mining in this country has such progress before been made, neither have more reliable records been published than during the short period of our existence, and this more particularly during the past year. There is, as you are perfectly aware, a good reason for this; and how much more preferable it must be, surely, that a paper upon which the writer would have to spend much valuable time and care should be published, not for the benefit alone of a small section of the mining community, but by an institution that would secure its publicity over the whole of the United Kingdom and in many districts beyond the sea where the members are located. Surely, I repeat, this is desirable, the object being worthy of our attention and continued exertions.

I need scarcely point out to you what our object is, or at least my reading of it, for unless we have a definite object in view, and federate with the full intention of carrying out that object, we shall gradually, although possibly slowly, as an institution cease to exist or accept a subordinate position. I maintain, however, we have an object, and that we are endeavouring to the best of our ability to further it. The improved education of all who are connected with the conduct of mines



of this country is our wish and intention ; not alone the younger branches, but those also who have passed from the tutored to the tutorial stage, and must act on their own judgment and discretion. I maintain that to each one of these the publications of the Institution are of value ; and I venture to submit that they are frequently consulted not only by the junior members of the Institution, but also by those who have had considerable experience in matters pertaining to mining work generally.

We are informed through the *Transactions* of the progress made in mining engineering, of the new forces brought to bear upon the working of mines, of the various applications of machinery for, if not altogether novel purposes, at least novel in character, and of new ideas applied to the working or development of mines ; in addition to diffusing through our Institution a general geological knowledge of the various mining districts of the world.

This I maintain is a work of considerable magnitude and importance, and one which is becoming more appreciated daily, and within a very short period will, I venture to hope and think, embrace every person in the United Kingdom connected with the supervision of mines.

The education of the mining engineer of the future must of necessity be of greater importance than in the past, when the mines of this country were worked only from the outcrop or from shallow pits. It is of necessity that he should be cognizant of the fullest and latest information in reference to the path in life he has chosen to follow. When we come to consider the importance of the positions occupied, the large invested capital of which they have charge, the lives which practically are entrusted to mining engineers, it appears to me that we as a body should not only suggest but insist that a most liberal curriculum be accorded to their education. It does not appear to me that any practical difficulty presents itself, and provided men of ability and education are to be drawn into the work (which to my mind is most desirable) ; they must upon entering it be assumed to occupy at least a position amongst the learned professions.

Within the last twenty years the amount of capital necessary to win and work coal at any given colliery has increased very considerably, and this will still more be the case as the mines at the outcrop become exhausted—a probability which applies in a greater or less degree to all the mining of this country. Presuming, therefore, that a modern colliery with all the necessary machinery and other appliances, both surface and underground, would cost, say, £100,000 (and there are many

that have had expended upon them a sum equal to more than twice that amount), surely the person that has to expend this should have had the advantage of a most liberal training. To economically spend this money to commercial advantage he must have had experience not only in mining, but also be well versed in mechanical engineering. The winding, ventilating, and hauling power necessary must be well considered, and for this purpose a good mechanical knowledge is absolutely indispensable.

I need scarcely point out that in the near future the whole or pretty nearly so of the collieries working coal at the outcrop will be exhausted, and their places can only be filled by sinking to greater depths and under very different circumstances both as regards capital, expenditure, and the difficulties that would in all probability be met with. Although we are not called upon to build a Tay bridge, still we are expected to be able to bore either a Channel or a Severn tunnel. Such works as these are being daily carried out by some one or other of our members, and under circumstances equally as trying, and requiring for their satisfactory completion considerable mining experience. I maintain that many of the modern sinkings, of which the greater number of us have had some experience, are more difficult in their conception, arrangement, and successful completion, than the Continental railway-tunnels that have of late years attracted so much notice in the engineering world.

When we come to consider the immense amount of capital invested and the interests involved, I shall be able, I imagine, to show, not only that we ought to be able to conduct mining operations with due knowledge, but also that our employers have a right to demand, and the public also, that the working of mines should be conducted upon lines that have been carefully thought out.

When speaking of the amount of capital invested in mining in the United Kingdom, I am perfectly aware that I am treading upon debatable ground, and so far as I know there are no published official statistics upon the question. I am, however, of opinion that no less a sum than £150,000,000 is invested in mining, without taking into consideration the rolling-stock required to convey the produce to its destination, or in fact anything beyond the money expended upon and at the mines themselves.

The Mining Royalties Commission, who have just issued their report, give us some valuable information, as it is now known that by the working of mines, royalties were paid during the year 1892 to the amount of £4,657,048.

I find that the number of persons employed in or about the mines of the United Kingdom during the year 1892 was 721,808, and according

to my previous informant (the Mining Royalties Commission) that during the year 1890, £43,000,000 was estimated to have been paid in wages to persons employed about them.

Taking these figures as a basis we may, I consider, assume that upwards of 3,000,000 people in the United Kingdom are directly dependent upon the mining industry for a livelihood.

This enormous industry, if I may so term it, is a larger employer of labour than all the railways of this country combined, which I believe only employ directly upon the lines themselves about 400,000 men, or only about one-half. This may possibly not apply to those indirectly employed by them, in the building of rolling-stock, locomotives, etc., neither do the mining statistics, because this part of the necessary work is carried out by independent firms who make a speciality of the manufacture of the articles required.

I think these figures alone make out a case for our Institution, whose members have the practical control of this immense capital, and also the care of the lives of over 700,000 workmen. The time cannot be far distant when our federation will be complete, and I am sufficiently sanguine that my successor in office will be able to report that we consist of every mining institute in the three kingdoms.

In saying this I would like to point out, that in my opinion it would be very undesirable for any Institute to lose its individuality; and I feel tolerably certain that all the objects we wish to obtain may be brought about without having removed from them their old names and other distinctive marks of originality. To these several Institutes our thanks as a body are especially due, they having for years piloted us through rough water, a labour of which we are now reaping the advantage in various ways.

The men who, to a great extent, are responsible for the lives of the workmen employed at their respective mines, appreciate their responsibility and are anxious for their welfare and safety. The number of fatal accidents in proportion to the number of persons employed has been decreasing for some years, and this I am inclined to suggest does not arise from the mines being less dangerous to work, or less inflammable gas being found in them, but from a cause otherwise explained, viz., a higher standard both of men, supervision, and discipline. There is no other means of obliterating in the future that great blot on our escutcheon—the explosions which periodically occur, a blot which, I am sure, is the wish and endeavour of each one of us, as far as we are able, to remove. That such a consummation may ultimately be brought about is our sincere desire.

I need only refer my readers to the numerous articles that have during the past generation been made in the education of the masses in this country, as a precedent for what we should seek to accomplish among ourselves. The education of the mining engineer should conform itself to the spirit of the times in which we live, a spirit which is certainly progressive. The idea originally was that only just sufficient education was necessary in a miner if his power being able to discharge the ordinary duties of his profession: but looking to the marvellous advances of science, more particularly as applied to mining, he must be prepared to take advantage of every point that may probably be useful in the work which lies before him.

After some little experience of the manner of holding the examinations for colliery managers' certificates, and the result from what I may term the point of view of an interested party, I do not consider them on the whole satisfactory. In saying this I do not wish to be misunderstood, for I allude only to the system upon which the examinations are conducted, and my remarks do not in the slightest degree apply to the different boards of examiners or to the examiners themselves. You are aware that these boards are not in the first place agreed as to the age at which the aspirant should be allowed to hold a first-class certificate of competency. This appears to me very undesirable: the difference in age is two years, the Lancashire district being of opinion that at the age of 21 the mining student is competent, while in the Midlands the prescribed age is 23. Now, supposing each district had the power of refusing to allow the holder of a certificate whose examination took place where the age of 21 was sufficient, to take charge of a colliery in that district where the minimum limit of age was 23, I could understand there might be some good reason for it, but in reality no such power exists. There are also other points upon which the examinations differ, when the object is very clearly stated to be for the same purpose, and it appears to me eminently desirable that there should be uniformity in every particular.

The two classes of certificates may for a moment appear to constitute a difficulty, but this in reality is not so, the second class being (as always) intended to include men of a very much lower grade, acting under the instructions of the holder of the first-class certificate.

The result of the working of the Coal Mines Regulation Act of 1873 has been of great service in this respect, for it has done good if by only fixing the responsibility; but it has accomplished far more than this. We have certainly found that men of a superior grade have been introduced, and with that a general reduction in the ratio of accidents as compared with the number of persons employed.

I would suggest that a central board, whose offices should be in London, have the control of all certificates of the first class, and that the examinations for these take place in London. The construction of the board, I would suggest, should be upon the same lines as at present, but the number of members reduced, and each inspection district should be represented.

The examiners should, as under the present Act of Parliament, be appointed by the board, but I would so far alter the present arrangement as to appoint professors of the various subjects, instead of as at present mining engineers, who examine upon all of them.

The examiners should consist of the following, each taking their own special work, and should report as under the present Act to the board :—
(1) a professor of mechanical engineering ; (2) a professor of chemistry ;
(3) a professor of electricity ; (4) a professor of mining engineering ;
(5) a board of mining engineers, consisting of one from each inspecting district comprised under the Coal Mines Regulation Act, to examine upon the technical subjects which may be desirable for the practical mining of his particular district ; and (6) the chief inspectors of mines.

The boards, as at present constituted, should be empowered to grant certificates of the second class, and the candidates for these might be examined at the local centres as now arranged.

It will have occurred to most of us, in the past twenty years during which the progress of mining has made such rapid strides, how absolutely necessary it is for those having the conduct of mines that they should be fully recognized as holding a position, in which not only the workmen themselves but the public also have confidence. The increased depths from which coal is now being brought, and in the future must still more be so, together with the large number of employes engaged in a mine, render it imperative that such works should be under the control of men of known ability. The distances which coal is now being brought to the shafts from the faces of underground works is considerable and increasing (in some cases reaching three miles) rendering it absolutely necessary for the supervising engineer to have a knowledge of science as regards engineering and chemistry, which was unnecessary a few years ago ; and then only in a few cases would the possessor of this knowledge have had an opportunity of making it of any practical value.

As an Institution comprising the mining engineers of this country it is our duty, and one I am sure we shall not shrink from, to point out the way not only by which their status should be improved, but also as a profession show ourselves equal to the task imposed upon us.

I may say, without fear of contradiction, that there is no profession upon which such a grave responsibility rests as ours, and of this we have daily experience. Not only are immense numbers of men working daily under the surface of the ground, each one of which carries a responsibility to us; not only have we daily to lower them from the surface but also to raise them, and this by means of machinery under the guidance of men who are not infallible. Surely that, gentlemen, is a position that we all appreciate to the utmost, and our great wish is to reduce so far as we are able the loss of life that I am afraid I must say is almost inherent in mining. Much of late has been done to improve the ventilation of mines, and without entering into details, one may say it has been a great relief to many of us interested in the conduct of fiery mines, and if our Institution had only been the means of reducing the loss of life by explosions, we should not have federated in vain.

We have much more than this, however, on our agenda-paper, and our duty lies in educating our profession so that not only do they fully recognize the sacredness of human life, but that the surroundings of the workmen also during the period of their employment should be such as to raise them as far as possible above the depressing influences that exhausting labour naturally brings with it. After every possible effort has been made in this direction, we then have to consider the reasons for which capital has been invested in the working of our mines; and our object also should be to make a return to the investors equivalent to the risk for the capital expended. I maintain that the two principles run hand in hand, for I find in well-conducted mines, in mines which are being worked on carefully thought-out lines, that there also we find the investors have, as a rule, received the best interest on their outlay.

Our Institution has a great future before it, and it only remains for those who are responsible for its conduct to guide it upon such lines as shall lead, not only its own members, but the mining industry as a whole, to look upon its teachings with respect. We must not keep altogether to the beaten tracks, but move onwards, otherwise we shall be looked upon as a clog to the wheel, instead of what we should be, and have the power to be, the recognized leaders of those natural, scientific, and mechanical forces that may be brought to the assistance of mining engineering in every branch of its work.



Mr. JOHN DAGLISH (Newcastle-upon-Tyne) proposed a vote of thanks to the President for his excellent address, which contained matter of interest to all and would be of still greater interest when printed. He (Mr. Daglish) hoped in the course of time that the whole of the mining and metallurgical institutes of Great Britain would federate with them; he understood that there was a probability of the federative movement extending to the Colonial institutes. The mining industry was so great that it was possible there would ere long be a federation of all the mining institutions of the British Empire. If he might venture, not to take objection to anything contained in the address, but to make a remark thereon, he would like to refer to the question of examinations for mine managers. Having filled the office of examiner for twenty years he might naturally be expected to know something about it, and having retired from that position he had no further direct interest in it, but he should deprecate very greatly the introduction of any collegiate element into the examinations for mine managers. These examinations were for efficiency only, they were not to test the ultimate knowledge of a candidate, as with collegiate examinations, but for a certain amount of knowledge sufficient to entitle him to the management of colliery works, and especially in the practical department. He ventured to think that object could only be obtained by the examination of candidates *viva voce* by practical men.

Mr. M. H. MILLS expressed his pleasure in seconding the vote of thanks.

The PRESIDENT acknowledged the vote. Far from joining issue with Mr. Daglish he would say that gentleman was quite correct. He was of the same opinion, namely, that no professor could examine in the details of mining, but he did think that the other subjects ought to come under the supervision of professors. He hoped, whether that was brought about or not, that the great object they all had in view—the raising of the standard of capacity of the persons who had the supervision of the mines of this country—would be attained. It mattered little in which way it was done, but it occurred to him that the examiners ought to be men who had not only a thorough, practical but a scientific knowledge.

Mr. JOEL SETTLE read the following paper on “Spontaneous Combustion in Coal-mines” :—

SPONTANEOUS COMBUSTION IN COAL-MINES.

BY JOHN SETTLER.

INTRODUCTION.

HAVING experienced considerable difficulties in sealing off gob-fires at the Layton mines, the writer thought that a paper dealing with descriptions of some of these fires and the present mode of working would be of interest to the members of the Institution.

The gob-fires referred to were dealt with and illustrated in the following paper here reprinted, at the Bullhurst seam at the Fair Lady pits, Leyton Colliery, North Staffordshire, the property of the Madeley Coal and Iron Company Limited.

Gob-fires have occurred in almost every form of working which has been tried with the object of preventing them. Whenever a gob-fire commences the sooner the sealing-off is completed the better, in order to exclude the air from the gob, to prevent it breaking into flame and igniting any accumulation of gas. As the Bullhurst seam gives little indication except the smoke, which is very quickly followed by fire, and as the seam gives off considerable hydrogen freely, an explosion is likely to occur should the fire burst into flame.

It must be understood that gob-fires can arise from a variety of causes: some have their origin in coal becoming crushed and powdered in breaks or cleats in pillars, subjected to great pressure.*

Occasionally there are small pillars of coal which, in consequence of the thickness of the seam and the steep inclination, cannot possibly be got with safety and are left, becoming a source of danger, as they may heat.

Occasional discharges of water from faults, etc., and moisture are conducive to the heating of the hussle or floor of the seam, consisting of a soft carbonaceous shale intermixed with streaks of coal and pyrites. That hussle, as well as coal, is liable to spontaneous combustion is proved by several dirt-heaps which have fired on the surface.

Fires of this description can be abated by a coating of sand 2 feet thick to exclude the air, but the fire still remains in a dormant condition,

* The writer produced a sample of dust or small coal out of a break or cleat.

and should the sand be removed, the heat which the heap contains would by the admission of air again revive into fire and give off a very nauseous smell.

Mines which give off carburetted hydrogen are exceedingly dangerous when gob-fires take place, and require constant attention.

The thermometer should be constantly observed, but should not be relied upon, as gob-fires have frequently occurred without any perceptible change in temperature—suddenly bursting into fire. It is, however, very desirable that the temperature of the return air should be daily observed, and any increase must be taken as an indication that the goaf is heating.

Generally speaking, the temperature of the Bullhurst return from the drift or goaf is 78 degs. Fahr. With one-half of the district heading-out and the other half drifting-back the main return is 74 degs. Fahr. with little variation.

The Bullhurst seam lies at a depth of about 500 yards, with a section consisting of :—

Rock roof.					Ft.	In.	Ft.	In.
Bass	...	...	...	...	...	2	0	
Coal, Tops	...	...	...	...	3	9		
Middles	...	..	...	...	3	0		
Wall coal...	...	...	...	...	5	0		
Billies	...	...	..	...	2	0		
						13	9	
Hussle ..	...	..	...	...	..	2	0	
Rock floor.								

The tops and billies are high-class steam coal; the middles and wall coal a superior quality of gas-coal and a very good house-coal; the slack produced, being of a bituminous nature, makes high-class furnace-coke.

The levels are driven in the middles and wall coals, the tops and billies being got when drifting-back.

The inclination of the Bullhurst seam is very irregular and contorted, varying from 15 to 70 degrees. The seam produces much fire-damp, and is very dry and dusty. There is practically no shot-firing, as the coals can be got without blasting.

TOP-RANGE BANG-UP, NORTH SIDE (Fig. 1, Plate I.).

In deciding what distance to leave against a sealed-off goaf, the dip of the mine must be taken into consideration, as shown by the following case :—

A very extensive fire, extending from A to B (Fig. 1, Plate I.), took place and was sealed off in October, 1883. Seven years after, a piece of coal was taken out below, leaving 50 yards of barrier between it and

the old workings: this was considered sufficient support, but proved to be inadequate. The angle of the seam being 35 degs. the coal slipped down until it thickened or communicated with the old workings lying above. A charged post which was found among the loose coals in the drift proved this conclusively. There was no indication of gas or gun smoke, but the district was sealed off promptly by three permanent stoppings at C. Drifting was then recommenced with the customary temporary stoppings erected at D (which will be described later on).

Top-stink was detected at E, and the district was sealed off on January 14th, 1891, with stoppings at D, and further temporary stoppings were put in at F: it was most fortunate that this had been done, as an explosion occurred and blew out the stoppings at D five days afterwards.

It was thought that the No. 3 or top stopping at C had become uncapped allowing the air to pass, re-ventilating the old fire at A and igniting an accumulation of gas. Luckily no one was injured, the explosion having occurred on Saturday night, January 18th, 1891, and was discovered, during the Sunday morning's examination, by the damage it had done, and a strong smell of after-damp. Prompt action was taken and the sealing off of the temporary stoppings further back at F was completed by 4 p.m. of the same day. This was not a moment too soon, as during the time of sealing off there were several suction of air, indicating that slight explosions were occurring in the goaf, and showing that the fire was still supplied with sufficient air to maintain its combustion. These explosions would no doubt in time have become larger and larger, and to prevent the air from going in to feed them required 30 yards of sand-packing along the three levels, all well pounded in, with brick-and-mortar stoppings intervening, as shown. Not only did the danger show itself in the workings at E, but the heat was revived at the point B, which is the main return airway, and extra strong work of brick-and-mortar was erected and the floor concreted.

The temperature taken in a 2 inches pipe at B, 5 feet below the floor, in sand, remained at 125 degs. Fahr. for a very long time, and at present it is 102 degs., showing, when a fire takes place, that the goaf retains the heat, and should it be able to get a further supply of air it would be speedily revived.

TOP-RANGE BULLHURST (Fig. 2, Plate I.).

Fig. 2 shows workings in which the places were being worked in descending order. Upon several occasions small pillars of coal were found to be heating, and were loaded out as quickly as possible.

On November 30th, 1891, at 7 a.m., a haze or steam with a slight smell of gob stink was perceived in the working-places of this district at the point G coming off the goaf, and after careful examination it was decided to take out all materials at once and complete the temporary stoppings at the points marked 1, 2, and 3, the other four stoppings having been previously completed with permanent packing.

We thought we were justified in making arrangements to draw out the materials, but were unable to do so. At 12 o'clock noon, a dense smoke appeared coming from the goaf, and the completion of the stoppings was pushed forward with all possible speed and completed by 8 p.m. of the same day, bricks and mortar being in readiness at each stopping. These stoppings were not relied upon and were further strengthened with sand-and-dirt packing.

It will be observed that there is a considerable distance from the goaf to where the temporary stoppings were erected, whereby much coal was lost; but in consequence of the angle of the seam being 55 degs. and the pillars being broken, there was no alternative but to erect the stoppings at the points 2 and 3, where the seam was practically level.

Temporary stoppings had been erected for sealing off this district at the points marked H, and were never allowed under any circumstances to be disturbed until another course of temporary stoppings had been substituted at a lower point.

This is the largest area of Bullhurst coal that has been wrought before taking fire.

BOTTOM-RANGE BULLHURST (Fig. 3, Plate I.).

Another principle of working the Bullhurst and other seams subject to spontaneous combustion was introduced some years ago by Mr. Frank Rigby at the Bunkers Hill collieries, which has proved very advantageous, and enabled them to be wrought with considerable success, and entire freedom from gob-fires up to the present time

In this system the coal is wrought in descending order, and as each pillar of coal is worked out on the rise a stopping is put into the level to prevent the ventilation circulating through the goaf; the next level below becomes then the return airway, and the goaf above becomes charged with gas, only allowing sufficient ventilation to pass to keep the edges of the goaf and working-places free from gas.

Fig. 3 shows the district where this principle was first adopted at the Leycett collieries; and as the drifts were finished permanent stoppings were put in, consisting of brick and mortar, and sand well packed.

It will be observed that the object of this system is to keep the ventilation off the goaf, by only allowing sufficient air to enter to ventilate the edges of the goaf and to keep the working-places free from gas, while the higher portion of the goaf is undoubtedly charged with gas. When it was safe to examine the internal parts of the goaf, gas was always found, but was not of an explosive character, about 3 per cent. being found on the edge of the goaf, showing that in this instance the principle worked very satisfactorily.

The temperature at No. 6 stopping registered 84 degs. Fahr., which was always the temperature of the return from this goaf.

The whole of the district was worked out successfully, and six stoppings were completed, as shown in Fig. 3. The district appeared to have a little haze or steam on the return from the goaf on several occasions, and it was always concluded that if the internal part of the goaf had been ventilated it would have taken fire.

Turning to another portion of Bottom-range Bullhurst, where only two drifts had been worked back, and the place, on account of the inclination of the seam running irregular (Fig. 4, Plate I.), had caused some little water to accumulate, which was pumped out. In a very short time (on November 12th, 1892) a peculiar gas, without gob stink, was observed to be given off, and stoppings were put in, treating it as a gob-fire. This gas was constantly given off without gob stink, and, so long as it continued, the strengthening of the stoppings by dirt packs was extended. The stoppings then appeared to have almost stopped the gas from coming off.

At 7:30 a.m. on December 13th, 1892, a great rush of wind occurred in the district, which was observed at the bottom of the downcast shaft, some 900 yards distant.

An examination showed that there had been an explosion in the internal part of the old workings where the gas had been given off, and smoke was found issuing freely from the drifts. There was no smell of after-damp, but a slight smell of gob stink, and the gas given off was of a heavy nature, no doubt deadened by the smoke emitted, and about 3 per cent. of gas was indicated upon the Mueseler lamp.

The customary precautions had been taken by erecting temporary brick-and-mortar stoppings at the entrance to the district; and sufficient bricks were at hand, only requiring mortar to seal off the same in case of emergency, so that the district was closed by 12 o'clock noon of the same day.

From time to time since it was sealed off this work has given a considerable amount of trouble. It has always been the writer's experience

that whenever a district gets on fire there is a very great tendency to draw in air, and extraordinary lengths of packing are required to prevent it; but if the district can be sealed off before it breaks into flame short lengths of packing will suffice.

BANG-UP BULLHURST, SOUTH SIDE (FIG. 5, PLATE II.).

The principle of working with the goaf charged with gas in the Bottom-range Bullhurst having proved successful, enabling the whole of the district to be worked out, it was decided to apply the principle to another district called Bang-up Bullhurst.

When the coal was got above the No. 5 level the first stopping was put in at No. 5, bringing the return air through No. 4 level. This stopping is 22 yards in length of sand, pounded in on the level with two brick-and-mortar stoppings of three feet thick.

As the district gave off a large quantity of gas the goaf was rapidly charged, and even with all this length of packing gas was emitted very freely from No. 5, the top stopping; the temperature of which was 84 degs. Fahr. for a considerable time.

When the drifts were worked out lower No. 4 stopping was inserted, consisting of two brick-and-mortar stoppings and 22 yards of sand-packing. No. 3 level now being the return, and the temperature 78 degs., which increased in about two months to 84 degs., and when the district was sealed off it was 86 degs. Fahr.

Temporary stoppings were put in at Nos. 1, 2, and 3 levels, consisting of 3 feet of brick and mortar with tub roads through them, and in all cases sufficient bricks were left at each stopping to close the district off promptly in case of emergency, all that remained to be done being to get mortar to each stopping, and build up the openings or tub roads.

It was calculated that it would take four hours at the outside to seal off the district, strengthening the same afterwards by more permanent work of lengthened sand-packing, etc.

The district had been worked out to the position shown, when it gave rise to great anxiety and careful watching, the temperature rising to 88 degs. at No. 5 in front of the stopping and 96 degs. against the coal. No. 4 also began to give off gas, the temperature being 84 degs. Fahr.

The gas at No. 5 stopping had a peculiar odour, and was very explosive. About 8,000 cubic feet of air per minute was passing this stopping.

A little haze appeared upon the ventilation at I, and as this had hitherto been an indication of gob-fire, the district was sealed off without delay.

The temperature at No. 5 stopping increased, commencing at 78 degs. and terminating at 88 degs. against the pack and 96 degs. against the coal on the head side of the level. The day after the district was sealed off the temperature at No. 5 stopping registered 80 degs., gradually falling within one week to 76 degs., and it has remained at the same temperature ever since.

Although the district was sealed off on December 28th, 1892, No. 5 stopping gives off gas freely to this day, Nos. 1 and 4 slightly, while Nos. 2 and 3 do not give off any gas.

It will be gathered from these remarks that Bang-up Bullhurst varied from the working of Bottom-range Bullhurst. When worked upon the same principle it caused great anxiety, in consequence of the large quantity of gas given off from the stoppings and the temperature reaching 96 degs., whereas the district (Fig. 3) worked on the same principle gave off very little gas, and the temperature remained constant at 84 degs.

Outside this district (Fig. 5) drifting was again commenced, and after some little time the hussle or floor was found to have heated very much, and would speedily have been on fire. Great difficulty was experienced in clearing it out, as the heat had risen from the hussle into the pillar of coal. This heat arose in a piece of troubled ground which might be termed more accurately a roll of dirt than a fault.

The writer mentions this circumstance because the origin of this heating was clearly traceable to the hussle or floor.

GENERAL CONCLUSIONS.

The greater the number of stoppings to be completed when a gob-fire takes place the greater will be the risk, as every delay adds to the danger and cost. The adoption of temporary stoppings will be found of the greatest possible advantage and to afford great additional security.

There should not be more than three openings to seal off. It is even better if only two can be arranged, that is, an intake and a return only.

The temporary arrangements which the writer recommends for working the Bullhurst seam are, to put in 3 feet of brick-and-mortar stoppings cut to a solid bed all round, that is passing all breaks in the coal and surrounding strata. Sufficient openings are left in the stoppings for the horse and journey to pass through. A sufficient number of bricks should be placed, close at hand, to complete the stoppings in case any symptoms of gob-fire are discovered. The only material required will be mortar, and in case of emergency such stoppings can be completed in three or four hours at the very most.

Brick-and-mortar stoppings must only be considered as temporary, and after the withdrawal of the men and allowing sufficient time to elapse (that is in case the gob-fire has shown serious symptoms) before an examination is made, so that the internal part of the workings sealed-off may become so charged with gas that there would have been an explosion if such danger existed. The result of the examination of the stoppings will be a guide as to what course is next to be adopted; generally, it will be found that explosive gas is being given off at the highest stopping, the lower or bottom one at the same time taking in air, to prevent which the defective parts should be plastered with mortar at the time of inspection.

After this examination it may be advisable to allow a further time to elapse before commencing to pack with sand or small dirt against the brick-and-mortar stoppings, but this should not be pressed forward too hastily, as the packing will sink, no matter however well pounded in. These temporary arrangements will be less costly if they are carried out, and the materials conveyed to the places determined upon, during working hours.

It is not advisable to have less than 30 yards in length of packing against the temporary stopping along the level of a sealed-off district, to prevent the fire from sucking in air, and to complete the end of such pack by a brick-and-mortar stopping not less than 2 feet thick, and plastered over with mortar to make any weakness more perceptible. This work may seem to be extraordinarily strong, but it will be required to prevent the goaf sealed-off from being disturbed when drifting is again commenced.

As the Bullhurst seam is of great thickness (13 feet 9 inches) it is surprising what large falls take place when drifting or bringing back pillars, and there might be breaks in the roof which would allow gas to escape from the internal goaf sealed-off. If that should be the case, the same goaf would take in air and give off gas alternately at one and the same point, that is, making an intake and return of the same place, causing danger to arise unawares.

With a view of leaving as little coal as possible, drifting is sometimes commenced in too close proximity to the sealed-off goaf, thereby disturbing or uncapping the old stoppings and reviving the old gob-fire. It is probable that more accidents arise from this cause than any other.

Fig. 6, Plate II., illustrates a method of economically and successfully working the Bullhurst seam in panels on the pillar-and-stall principle by which only two stoppings are required to seal off the district, and a new district may be headed out ready for drifting when the one adjoining is finishing.

Fig. 7, Plate II., illustrates a method of working seams on the long-wall principle, but it is not applicable to the Bullhurst seam, on account of its thickness, inclination, etc.

The principle recommended for working a mine subject to spontaneous combustion with safety is not to open out too large an area of coal in one district, so as to enable the same to be worked and sealed-off before it even gives indication of gob-stink: it also gives further advantages, as the workings can approach closer to sealed-off districts with greater safety if they have not taken fire, and the loss of coal will be considerably less.

Levels should be driven to the boundary, and the panels worked back in all cases, so as to leave the sealed-off goaves behind.

A piece of coal 100 yards on the level by 80 yards on the rise is probably the safest and most convenient size for working in thick seams of steep inclination, subject to spontaneous combustion.

In thin seams a larger area of coal might be determined upon according to circumstances.

The following fundamental principles should be observed:—

- (a) Do not try to work out too large a district at once.
- (b) Districts should be worked out as quickly as possible, and sealed off when finished, whether they have taken fire or not.
- (c) Leave sufficient support of coal so as not to disturb sealed-off districts.
- (d) Preparatory or temporary stoppings should always be erected.
- (e) The quality of gas given off from a goaf should be carefully noticed.
- (f) Note any change in temperature from the goaves.
- (g) Do not pass more ventilation through a district than is sufficient to keep the working-places and gob-edges free from gas.

The writer particularly desires to mention that Mr. Atkinson, H.M. Inspector of Mines, has taken great interest in the working of this mine, and has seen all the districts referred to.

Mr. E. B. WAIN (Stoke-upon-Trent) wrote that the special point in this paper was the exceptional circumstances described under which the gob-fires had been dealt with. The paper was especially interesting as following that on the same subject read at the last Federated Meeting,* in which Prof. Lupton gave a general description of the manner of occurrence and methods of dealing with fires under what may be termed

* *Trans. Fed. Inst.*, vol. iv., page 481.

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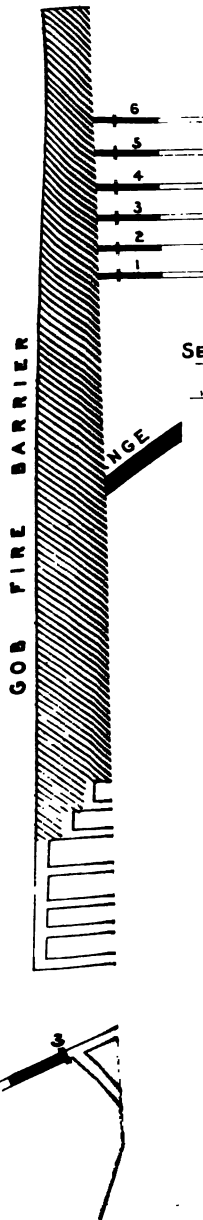
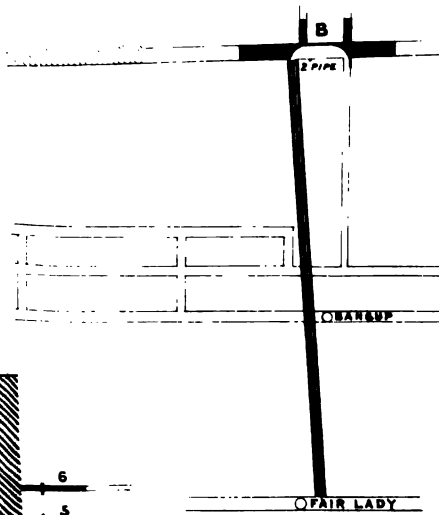
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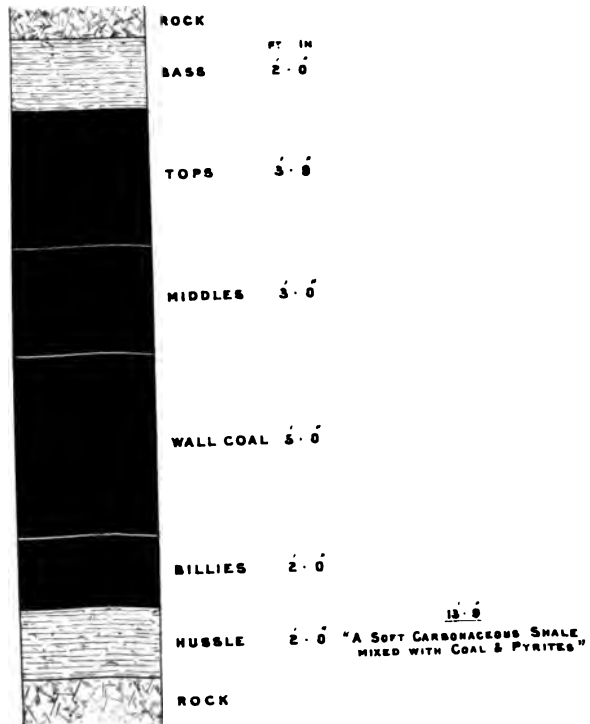
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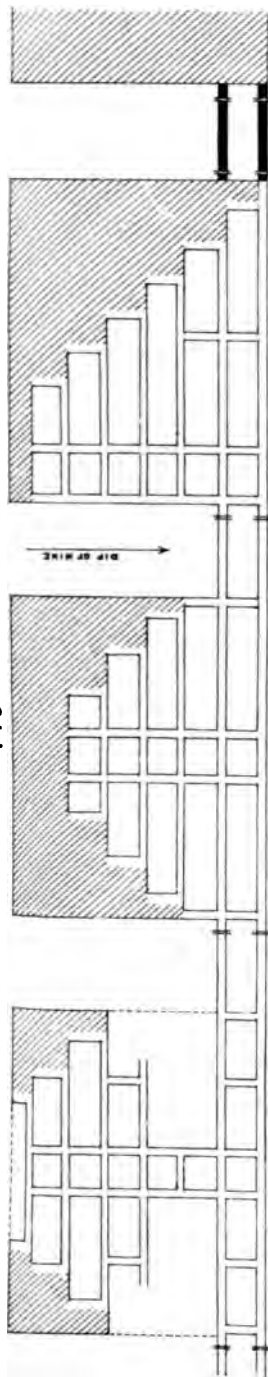


SECTION OF BULLHURST SEAM.

Scale- 5 1/2 Feet to 1 Inch







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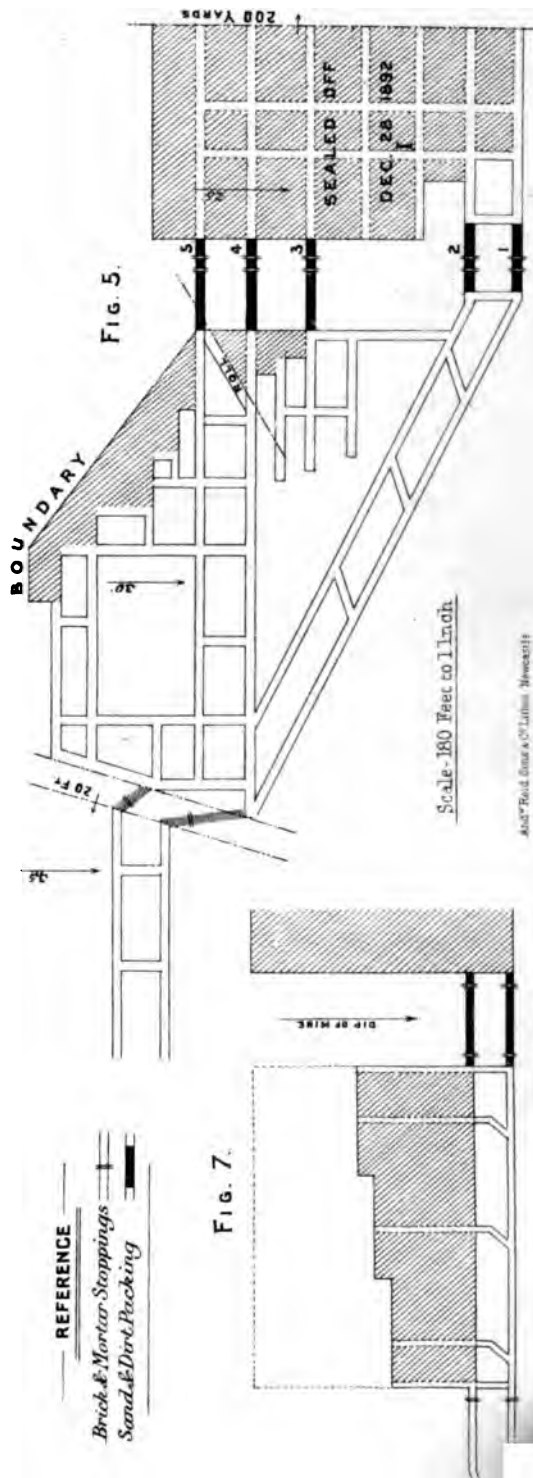


Fig. 5.

FIG. 7.

Scale-180 Feet to 1 Inch

6325 Ford Court, A/C Lithium, Newcastle



ordinary circumstances, in Derbyshire, Leicestershire, and Warwickshire, where the easy gradients and small volumes of fire-damp rendered the operations, in dealing with such outbreaks, comparatively simple. Mr. Settle, however, takes up the question of dealing with fires which have occurred under most exceptional circumstances, where the heavy gradients (up to 70 degrees), the fiery nature of the seams, and the thickness of the coal rendered the operations much more difficult; and the greatest possible credit is due to Mr. Settle for the thorough manner in which he had dealt with the outbreaks he had, from time to time, had to contend with at the Leycett collieries. Notwithstanding the exceptional difficulties under which the work had been done, it had been carried out in such a manner as to reduce the danger to a minimum; and although, some years ago, before Mr. Settle had charge of the colliery in question, serious loss of life had resulted from explosions arising from gob-fires, the methods which he had originated and carried out had proved to be thoroughly successful in preventing similar disasters. In considering the subject, however, it is impossible not to feel regret that it should be necessary to sacrifice so large a quantity of most valuable coal in pillars and barriers, in districts closed from fire, as a safeguard for future workings; and one was led to ask the question, whether some means could not be devised by which such loss might be avoided? The system which had been adopted at some of the collieries in the Warwickshire district, and which was briefly mentioned in Mr. Lupton's paper,* appeared to be particularly applicable to such circumstances as those which the paper under consideration referred to. If a number of dip headings were driven down to the deep boundary, and so arranged that one engine might draw out of several of them, and the coal was worked out with a longwall face advancing from dip to rise, any water there might be in the mine would fill up the workings as the face advanced and effectually prevent any spontaneous combustion in the goaf. Even if there were no water in the workings, they could easily be flooded if any danger from fire was apprehended, without in any way interfering with the progress of the coal-getting. Another distinct advantage of such a system would be the absolute avoidance of any danger arising from fire-damp, as the numerous dip headings from which the coal was drawn would effectually drain any gas produced at the working-face. At first sight it would appear, from the numerous engine-brows, that the hauling arrangements would be unnecessarily complicated, but this would not be so. The writer has seen, in the Nottinghamshire coal-field, somewhat similar arrangements working very

* *Trans. Fed. Inst.*, vol. iv., page 484.

satisfactorily: the only difference being that, instead of the face advancing from dip to rise as proposed, and the coal being drawn through the solid roads, the workings were advancing with a dipping face and packed roads. An engine-brow was taken down the centre of the work with cross-gates driven from it at an angle of 45 degrees, and branch-gates parallel to the centre gate-road turned off the cross-gates at suitable intervals. By this arrangement the trams were worked to and from the actual coal-face by the plane-rope, and one engine and rope served twelve or more stalls. In the plan proposed for working up-bank through solid roads similar arrangements might be used, or the main-plane and cross-gates could be worked by an endless-rope, and drums driven by friction-gear from a belt-rope used to draw single tubs up the branch roads to supply the main-rope. The plan had many features to commend itself; absolute freedom from gob-fires, no danger from fire-damp, and the cost of hauling and maintaining the roads reduced to a minimum. The only apparent drawback was the large initial expense in driving out dip headings to the boundary, but this would be more than repaid by the reduced cost of working, and the greater safety ensured.

Mr. SAMUEL SPRUCE (Tamworth) wrote:—As one would expect from the author, this paper was highly interesting and instructive, as showing the methods adopted to get quit of the gob-fire in the Bullhurst seam at Leycett colliery. There were, no doubt, peculiarities attaching to this colliery, in the thickness of the Bullhurst seam and the high pitch of the mines: one perhaps was the very wide rib which appeared to have been rendered necessary on account of the angle of the seam being as high as 55 degrees. He (Mr. Spruce) did not know an instance where so large a rib had been permanently left on account of gob-fire; but he had known cases in which a whole district required to be dammed off—because the excessive heat prevented a nearer approach to the part on fire—and left for a year or two, or even more, before again approaching it; and possibly had the same plan been practicable in this case, and the district remained closed a sufficient length of time, a rib of less width might have sufficed ultimately. Apart from this question, however, there were some points in common, as regards gob-fires, with other seams in other parts of North Staffordshire and other places; he was, generally speaking, in agreement with the author of the paper, though in some respects he differed slightly. The methods adopted with regard to the stoppings at Leycett colliery appeared, so far as he understood them, similar to those adopted and used in nearly all kinds of seams, thick and thin, both in Shropshire, Staffordshire (North and South), Worcestershire, and

Warwickshire, to his knowledge during the past fifty years and more, where gob-fires have occurred ; except that he had never known it necessary to put in the great length of stopping mentioned in the paper of "30 yards of sand-packing along the three levels, all well pounded in, with brick-and-mortar stoppings intervening, as shown." He would like to know whether this was not an extremely exceptional case, even in these steep mines ? and he would like to learn also what kind of strata there were above the coal, to the extent of about three times the thickness of the seam ? He noticed it particularly as being "on the level," as this would appear to assume that an unusually thick rib, from dip to rise, was also necessary to support these 30 yards of stoppings, at least as wide as the length of the stoppings themselves ; and also whether, in the experience of the author, a 50 yards rib was necessary if the panels were worked in ascending order ? He entirely agreed with Mr. Settle that "whenever a gob-fire commences the sooner the sealing-off is completed the better." He (Mr. Spruce) affirmed in his paper on "Pit Fires," read before the members of the North Staffordshire Institute of Mining and Mechanical Engineers, in June, 1885,* that beyond a certain limit "atmospheric air is the greatest promoter of gob-fire which can be found," and that it is necessary "in the first place as early as convenient" to "exclude from the gob-heaps atmospheric air entirely ;" but he also expressly pointed out at the same time that this was a totally different thing from crippling or even reducing the general ventilation of the working-places of the mine, with which some people appear to confound it. He did not know whether the writer of the paper had been moved to some of his remarks in consequence of what was said at the Derby meeting, where the notion appeared again to crop up that ventilation would cure gob-fires ; but his observations came in very appropriately. He (Mr. Spruce) had no doubt that the writer did not put in any of the dams referred to in the paper, with the object of turning a current of air upon the gob-fire with the view of curing it. Was it not somewhat singular that however often this notion of curing gob-fire by ventilation might come to the front, as it had done from time to time for many years past, it was advanced only as a speculative proposal, and never, so far as he was aware, had it been accompanied by proof from actual experiment that any extensive gob-fire had really been subdued by that method. Nor was it at all made clear by any well-authenticated case that increased ventilation had ever prevented, or even retarded, a real gob-fire of any important dimensions. A small fire, such as could be loaded out, might be got rid

* *Trans. North Staff. Inst.*, vol. viii., page 38.

of by being brought into the open, where it would either be extinguished from separation or burn itself out. He had known instances in which heating gob, or rather the slack improperly left as gob, taken out before it had actually caught fire, had (on being loaded out) broken into flame on its passage to the surface. He (Mr. Spruce) had known actual fire prevented in the Thick Coal seam, when imminent, by temporarily cutting off the ventilation, from the side of work or panel in which it occurred, for three nights and two days, generally at the end of each week for several weeks, until the extensively worked side was entirely cleared out in safety and with comparative comfort on the remaining days, guided by the sense of smell on the part of the manager, or someone else who had that sense sufficiently developed, and in whom reliance could be placed as to when to work and when to cease working. This fact related to a side nearing its completion, but he had also known, in the Thick Coal seam, the same thing to occur on a very much larger scale, in which a large side of work had indicated imminent gob-fire—known by the same means as well as by the increasing temperature of the heating slack; and here it was well known there was nothing else but the slack left therein that could fire, there being an underclay floor, no parting in the coal saving 7 inches of sandstone known as “hard stone,” the upper coal still hanging, therefore no roof had fallen, and the loose wrought coals being all drawn out. The side of work, being as designed, 70 yards by 90 yards in about mid-working, was closely sealed up, and kept so for a period of three months, and then again opened, when all apprehension of fire and gob-stink was entirely gone, and the work resumed as usual and carried to a successful end. But such a result as this must not be looked for if the gob had passed the stage of “fire-stink,” and actual fire had once got a good hold of the slack. He (Mr. Spruce) had known seven years of close sealing insufficient to be quit of this, that is to say, it would quickly revive into active fire on the re-admittance of atmospheric air. Of all the ineffective measures for dealing with real gob-fires, or gobs readily given to fire, that of using clay in “wax walls,” as it is called, was—speaking always within his (Mr. Spruce’s) experience—the worst. He thought it ought rather to be regarded as a fire-promoter than a fire-preventer; at any rate any gob that would do with it would do equally well without it. Just thirty-five years ago he became acquainted with this process in a Warwickshire colliery, in the Seven Feet and Deep Coal seams worked by longwall, where the fires in each seam were so extensive under this system that the colliery—while not half worked out—was on the point of abandonment after nearly ruining its owners, who offered, and

were only too glad, to part with it and all the plant—raising over 2,000 tons weekly—for an insignificant sum. A gentleman, well versed in Colliery working, and who had had large experience in gob-fires, and knew generally how to deal with them, was ready enough, indeed was anxious, to embrace the offer and to purchase. But he hesitated to do so on account of these tantalizing and ruinous fires, of which it is not too much to say that for hundreds of yards along the return air-courses and some gateways livid fire was at intervals visible, only kept in partial abeyance by this clay-dabbing, on which from 17 to 25 men and boys had for a long period been constantly engaged in daily and nightly work called “waxing the carvings.” It was only by the strongest assurances that the whole system could be changed in a month or so without further danger and at little expense, that he did ultimately purchase. The system was accordingly changed, but still working longwall, and from that day to this—for the colliery was still going, and would continue for many years—not a pound of clay had been used for that purpose, nor had there been any but the most insignificant of gob-fires, only just sufficient to show that such fires would still prevail if permitted. Here and elsewhere there were thousands of yards of gob-roads; one pit in one seam had now over 3 miles of gob-roads open, and no clay had ever been used or needed, and never would be. He (Mr. Spruce) thought there would never be found in any seam worked by longwall any gob-fire (using this term in the proper sense), so long as not less than 1,400 tons of coal for every statute acre for each foot of thickness of the entire seam was extracted and sent out of the mine.

Mr. G. J. BINNS (Netherseal) asked whether bituminous or non-bituminous coals were the more active in causing spontaneous combustion? It seemed to those managing mines in which spontaneous combustion was rife, and in which gas was infrequent, to be a dangerous state of things to have so much gas; he supposed, however, that in the district Mr. Settle represented they were used to it. He had found that clay stoppings—though not in the form of wax walls—in place of brick stoppings gave way without breaking under pressure, which rendered the brick stoppings useless.

Mr. W. N. ATKINSON (H.M. Inspector of Mines, Newcastle-under-Lyme) said the spontaneous combustion of coal in mines was of special interest in North Staffordshire, because in that coal-field such combustion frequently occurred in seams producing much fire-damp and very dusty; so that in addition to danger from the fire itself there was risk of serious explosions. The Bullhurst seam at Leycett colliery, in which the gob-fires

described by Mr. Settle took place, was both gassy and dusty, and its liability to spontaneous combustion was therefore a source of great anxiety, and the successful way in which Mr. Settle had dealt with a number of gob-fires had only been accomplished by very great vigilance and care. Spontaneous combustion in mines was until recently most frequently attributed to the presence of iron pyrites in the coal, but it was now understood to be due to the oxidation of the coal itself, or of carbonaceous matter associated with coal, and the presence of iron pyrites might be favourable to spontaneous combustion, but it was not a necessary element. There are, however, no means, except experience, of telling whether any particular seam of coal would be liable to gob-fires, nor why some seams were extremely liable to gob-fires, others slightly so, and others not at all. In North Staffordshire spontaneous combustion occurred under varying conditions. The great majority of fires began in the gob, but cases were known where they had broken out on roads or in pillars of coal. They gave warning of their presence first by the characteristic gob-stink, and then by emitting vapour and smoke; but in some cases these warnings were so slight, or of such short duration, that they were not observed until the combustion has arrived at the stage of actual fire. In other cases indications of incipient combustion were observed for several days or weeks before there was red heat or flame, and sometimes the heating abated without reaching the stage of incandescence. Certain conditions were generally held to be conducive to gob-fires in seams liable to spontaneous combustion. One of these was the presence of coal in the gob; this should be avoided as much as possible, but it was often impracticable to get the whole of the coal or to prevent coal being left in the gob. Impure, disturbed, or faulted coal in some seams was supposed to be peculiarly liable to spontaneous combustion. Water or moisture was sometimes held to be an exciting cause. One gob-fire, which came under his (Mr. Atkinson's) notice, occurred a few months after the use of water was adopted in the district for damping dust, so that gunpowder shots might be fired, but several gob-fires occurred in the same seam at a neighbouring colliery without such an exciting cause. It was sometimes supposed that pressure or friction caused spontaneous combustion in mines; beyond that by crushing and pulverizing, the coal was rendered more liable to spontaneous combustion from other causes, he failed to see that pressure or friction had any effect. There appeared to be some difference of opinion with regard to the effect of ventilation on gob-fires. Some engineers were in favour of strong ventilation and others advocated as feeble a ventilation as practicable. By acting as a cooling agent, venti-

lation might prevent spontaneous combustion, but the majority of gob-fires occurred in inaccessible situations where the ventilation, however strong, could not act as a cooling agent, and the stronger the ventilation the more difficult it was to prevent feeble currents passing through the gob, and this appeared to be one of the most common exciting causes of gob-fires. He might mention the case of a colliery where the Bullhurst seam was worked for several years with a comparatively feeble ventilation without any gob-fires occurring; a large fan was then erected at the downcast shaft, which was made the upcast. For some months the fan ran at a reduced rate owing to its shaft heating, but nine months after it started, the first gob-fire was discovered in the pit and there had since been several serious gob-fires. The *débris* round the top of the shaft and fan-drift also took fire, probably owing to air being drawn through it into the shaft and fan-drift, the brickwork of which was not airtight. The Royal Commission on Spontaneous Combustion of Coal in Ships condemned the attempts which had been made to ventilate the bulk of the cargo, alleging that such ventilation as could be applied for that purpose was conducive to spontaneous combustion, no doubt for the same reason that slight currents of air passing through a goaf were favourable to gob-fires. The idea of excluding air from the goaf was the basis of the system practised by Mr. Rigby, at Bunker's Hill colliery. When the goaf was to the rise it was allowed to fill with gas, and when it was to the dip it could be filled with water. It might appear objectionable purposely to allow a goaf to become charged with fire-damp, but if it prevented gob-fires it would be more of a safeguard than a danger, and it must be remembered that it was often impossible to prevent a goaf becoming charged with gas. By adequate ventilation the working-places might be kept free from gas, and if shot-firing was not allowed the risk was reduced to a minimum. In the case of the Bang-up Bullhurst, south side, at Leycett collieries, the system was a partial failure, as indicated by the temperature of 96 degs. Fahr. observed at No. 5 stopping, but in this case it was possible that the heating had begun before the air was prevented from passing through the goaf. The usual method of dealing with gob-fires in North Staffordshire was to isolate the places where they occurred by airtight stoppings. It was seldom possible to dig the fire out, and except in rare cases it would be dangerous to try to do so. The stoppings should be made as tight as possible, and afterwards strengthened by stowing, so as to resist an internal explosion should such occur. The preparatory stoppings described by Mr. Settle and the restriction of the number of openings required to be stopped were of the greatest assistance in dealing with a gob-fire.

Sir GEORGE ELLIOT, Bart., said the subject was a very interesting one, and perhaps they could discuss nothing with more advantage to the Institution or mining engineering practice generally. He had been connected with coal-mining in the particular district referred to, for the past thirty years at Harecastle colliery, drawing perhaps 1,500 tons per day, and they had had many gob-fires; the coal lay at various angles and the Bullhurst seam varied from 5 to 14 feet in thickness. Gob-fires were a great expense, and a great nuisance; but mining engineers got into the way of trying to understand them as time went on, and he was glad to say they had not suffered very much recently, owing to clear and distinct attention being given to the early symptoms which arose by smoke and smell—which should be dealt with promptly. The system they had practised for the past twenty years had been the entire exclusion of the atmosphere: his long experience and great practice had led him to direct this to be done with the assistance of the very competent engineers he had under him (Mr. Craig, Mr. McGowan, and other clever men), and he thought it would be right for him to state that he thought Mr. Settle had done well to bring this subject before the Institution. At the present time he was rather largely concerned in an extensive colliery near Halifax in Nova Scotia. The manager came from North Staffordshire, the mine was on fire from spontaneous combustion, and he would be very well satisfied if the cost of the difficulty did not exceed £40,000 or £50,000. He supposed the fire would be mastered eventually, the difficulty was that, when it was believed to have been overcome, the atmospheric air seemed to be let in too early and fired the whole place again. He would impress upon all concerned in like difficulty, to deal with the matter promptly and to exclude the air as effectually as possible. The remedy which had been suggested of taking out 1,400 tons of coal from every foot thick per acre would, he thought, be a good one, for if they could work this quantity he thought there would be none left, but he had known spontaneous combustion to occur where practically no coal had been left. In the Harecastle district there was an oil-shale in the vicinity of the Bullhurst seam, and he had known fires started by spontaneous combustion after the coal had been removed. The evil they had to deal with was the constant lighting up, and, he believed, the sovereign remedy was careful watching, and to work their districts, if possible, in panels so as not to have too large an area exposed.

Mr. G. E. COKE said he had lately had the opportunity of tracing the source of an underground fire in a rather unusual way. In a colliery with which he was connected, the deputy, in his morning inspection, found smoke coming out of the returns, and on following it to its source he

found that a shot had been fired the previous night, and the dust had taken fire and been burning all night. When the deputy got to the place he found that the coal was incandescent, and if this discovery had been delayed, the consequences would have been most serious. This might afterwards have been put down as a gob-fire, and he mentioned the case with the view of asking whether it were not likely that other supposed gob-fires might sometimes be traced to similar causes?

Mr. T. A. SOUTHERN (Derby) supposed Mr. Coke did not infer that all gob-fires were due to such causes.

The PRESIDENT mentioned that he had had a precisely similar experience in South Wales.

Mr. G. E. COKE said he had only mentioned the case as showing the importance of being able to trace the source of fire.

Mr. H. W. HUGHES (Dudley) said he did not wish to say anything at length on this subject now, as the South Staffordshire Institute had arranged to start a special discussion on the subject, and he had written an introductory paper dealing with the various theories to which spontaneous combustion was supposed to be due. However, he would like briefly to confirm Mr. Settle's final conclusions, and to say that, broadly speaking, the majority of them were supported by the experience they had gained in working the Ten Yards coal in the South Staffordshire district. There was no question in South Staffordshire as regards *a* and *b*, that they were proper precautions, and especially that which recommended the districts being sealed when finished. He agreed that sufficient coal support should be left; but he also agreed with Mr. Spruce that it had never been found necessary to leave ribs so strong as 50 yards wide. He considered the case Mr. Settle cited to be an exceedingly exceptional one, the seam being practically vertical, with the result that the weight and cracks might pass over the barrier and affect workings very much farther to the dip than if the seam had been only slightly inclined. He thought everyone who had actually worked Thick Coal admitted that up to a certain point the more air they could get into the workings the better. Mr. Spruce was an old South Staffordshire mining engineer, and therefore he was surprised at that gentleman expressing a contrary opinion. No one, of course, would be so foolish as to say that the best way to put out a gob-fire was to put on more air. It might be true in a literal sense that ventilating a gob would prevent fire, but he supposed it was practically impossible to ventilate any gob, as they could not get in enough air to cool it. They could supply sufficient oxygen to assist the oxidization of the organic constituents of the coal, but not enough air to cool down the

heating. Mining engineers, in speaking of "solid coal," broadly applied the term to any coal which was not in process of working; consequently, pillars of 50 or 60 yards square were spoken of as solid coal. Such pillars did fire, and there were many instances of such occurrences; but at the same time, when they did fire fissures were always found. He did not think there was any question, so far as their practice went, that, supposing it possible to introduce enough air, if they did so they would probably put out the fire. There were no instances on record of coal ever having fired in the solid, literally so called; of course he spoke in a literal sense, and by "solid" he meant to say coal which was not cracked. Mr. Binns asked for information as to whether a highly bituminous coal was more likely to fire, or whether steam-coal and coal of that class was more subject to outbursts. From his own experience he could not say, but, with the exception of one author, every one who had written on the subject from the time of Dr. Percy (thirty years ago) to the present day, considered that coals which contained a large quantity of oxygen were most liable to spontaneous combustion. Of all the known coal-seams those most liable to spontaneous combustion contained a large quantity of bituminous matter; coking-coals were more free, if not entirely free, from such action; and there was no instance on record of an anthracite-mine ever taking fire spontaneously.

The PRESIDENT said that Mr. Settle had given in his paper actual cases of gob-fires, and detailed how he had dealt with them, which was an advance in the right direction. He was personally in agreement with Mr. Settle's views, and he thought no man would take a large volume of air and force it into such workings as described in the paper. He had seen mines which, under natural circumstances, were very hot, and, when cooled down by ventilation, the danger would pass away, whereas in other collieries a large volume of air would quickly cause a serious underground fire. He was sorry that Mr. Spruce was not present to-day to follow up the remarks which the Secretary had read respecting wax walls. He had worked out large districts of coal, subject to spontaneous combustion, by using wax walls; but their value depended entirely on how they were applied. He did not quite follow Mr. Spruce in his remark as to taking out 1,400 tons to the foot per acre reducing the liability to fire. He might mean, as they had already been told, that they were to take out all the coal, and so leave no liability to spontaneous combustion; but this did not agree with his (the President's) experience, for combustion was not always due to small coal being left in the mine. One could not help thinking that the only proper way to work a seam which was

liable to spontaneous combustion was to work it so that should a fire arise they were in a position to dam off any affected district. Engineers were not immaculate, and could not possibly look after every detail which might be considered necessary in the workings of a mine liable to spontaneous combustion; but he could not too highly endorse Mr. Settle's recommendation not to try to work too large a district at once. Mr. Settle had placed facts before them in a way in which they had not been presented to them previously, and he suggested that the paper should be referred to the local Institutes for further discussion.

Mr. T. E. FORSTER (Newcastle-upon-Tyne) asked Mr. Settle to give a section of the rock-roof above the seam of coal, whether any seams of coal lay immediately above it, what amount of coal was extracted, was the whole of the coal filled, or was the small coal cast back into the gob, and what amount of coal was lost?

Mr. M. H. MILLS (Nottingham) asked if there had been any serious endeavour to work out the entire seam?

Mr. JOEL SETTLE, replying to the discussion, said that in working the Bullhurst seam at Leycett collieries they had no other course but to work out small districts. Mr. E. B. Wain suggested that the winnings might be driven to the dip and the coal worked upwards, filling the gob with water. The suggestion was a good one, but could not be applied to the cases described in his paper, as the mine was so irregular in its inclination that it would be impossible to make one main engine-dip. Mr. Spruce had taken exception to 50 yards of barrier-coal being left to support the sealed-off goaf. He should take into consideration that the angle where the coal was left was 55 degs., and they had absolute proof on the table before them that even there a charred post had come through the barrier, proving it to be insufficient. If they did not leave sufficient coal they would be subject to unknown dangers; the fires would be resuscitated, and no doubt explosions would occur in internal parts of the goaf; then as time went on the difficulty would be increased, and they would not be able to get their men to approach such workings. When he went to Leycett collieries there had been so many accidents from gob-fires and so many lives lost, that when a gob-fire arose every man ran out of the pit. The first gob-fire he sealed required nineteen stoppings, and if they had to attend these personally it made them consider the matter seriously. After a deal of thought, and knowing that he ran a great amount of danger, he concluded that the only safe way to reduce the danger was to reduce the number of stoppings to two or three, and by adopting this course he had been able to seal-off a district in about three or four hours from the first

discovery of the fire. With reference to the nature of the coal he might say that the Bullhurst seam was of a bituminous nature, and, regarding Mr. Binns' objection to the fundamental principle, *g* ("do not pass more ventilation through a district than is sufficient to keep the working-places and gob-edges free from gas"), he hoped it was explicit enough to all that they were not working with the colliery full of gas; no doubt all the reports from the foremen that morning would be that they were free from gas. By working the seam in descending order a slight show of gas would be generally found at the edge of the goaf, while the gas in the internal part of the goaf would extinguish light without exploding. He was very pleased that Sir George Elliot, who had a large interest at stake, generally approved of the suggestions contained in his paper. He knew several instances of coal having been found on fire in pillars, and Mr. W. H. Wain would confirm his statement. He would be very pleased to attend any of the local institutes if the discussion on his paper could be held on a day convenient to himself. He might say that the rock-roof above the coal was of great thickness; the next seam of coal (the Eight Feet) was 50 yards above, and it also had a very hard roof, with the exception of about 2 feet of bass, which lay at the top. All coal possible was extracted, and all slack was sent to the surface and used for coking purposes.

A unanimous vote of thanks to Mr. Settle was passed.

Mr. BINNS read the following paper on "Mining in New Zealand":—

MINING IN NEW ZEALAND.—(CONTINUED).*

BY GEORGE J. BINNS.

PART III.—COAL-MINING.†

Richly as the colony of New Zealand has been endowed with metaliferous ores, and plentiful as the natural stores of hydraulic power undoubtedly are, a great want would have existed had the deposits of mineral fuel been either deficient in quantity or quality, or so situated as to be approximately inaccessible. This latter point is not perhaps of so great importance, for while poor quality and small quantity are defects which can never be overcome, means of transport can always be devised. And this is, in the present case, fortunate, for while the coal-fields near the populated districts contain usually the inferior class of fuel, viz., the pitch coals, brown coals, and lignites, the true coals are found only on the inhospitable west coast of the South Island, to which reference has already, in a former portion of this paper, been made. The dangerous rivers and rough topography of this locality have greatly retarded progress, even in the case of metalliferous mining (where such comparatively small quantities of material have usually to be dealt with); and in the case of coal-mining (where a great bulk must be moved to render the industry profitable), the hindrance has been even greater. Still, notwithstanding the great natural obstacles, and in spite of the cheapness of imported supplies, the coals of New Zealand are slowly but surely making their way, and establishing in the colony a healthy, steady trade, not subject to the violent fluctuations and vicissitudes of gold-mining, but growing and strengthening year by year.

In this paper the following order will be observed :—

1.—Geology and distribution.

2.—General notes on the coal-fields.

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|---|---|---------------|
| (1) Auckland coal-fields. | } | North Island. |
| (2) Mokau coal-fields. | | |
| (3) Picton coal-field. | } | South Island. |
| (4) Collingwood and Takaka coal-fields. | | |
| (5) West Coast coal-fields. | | |
| (6) Canterbury coal-fields. | | |
| (7) Otago coal-fields. | | |
| (8) Southland coal-fields. | | |

* *Tran. Fed. Inst.*, vol. iii., page 644, and vol. iv., page 59.

† *Ibid.*, vol. iv., plate VII.

- 3.—Methods of working.
- 4.—Machinery.
- 5.—Legislation.
- 6.—Accidents.
- 7.—Total consumption, output, imports and exports, etc.
- 8.—Quantity of existing coal.
- 9.—Wages, strikes, benefit clubs, condition of the miners, etc.
- 10.—Conclusion.

1.—GEOLOGY AND DISTRIBUTION.

The geology of New Zealand is both interesting and complex, and although the Director of the Geological Survey (Sir Jas. Hector, F.R.S.) has, with the small staff at his disposal, done wonders, it cannot be expected that in an exceedingly rough country like the one under discussion, anything like the detail of the British maps should have been attained. As the age of the coal-beds has, at various times, been disputed, it will perhaps be better to give the Director's own words on this important question :—

“THE LOWER GREENSAND AND CRETACEO-TERTIARY FORMATIONS (CRETACEOUS SYSTEM OF ROCKS).—The true and almost only coal-bearing formations of New Zealand. It is no doubt true that there are valuable deposits of fossil fuel occurring in various parts of the colony that have been variously referred to different geological periods during the past history of the Geological Survey, and the age of which is not yet satisfactorily determined. Some of these are now known to be of younger date than the Cretaceo-Tertiary period, viz., various deposits of lignite in the Wellington district of North Island, and possible occurrences of the same material in the Nelson and Westland district of the West Coast of the South Island; also a deposit of the same nature found at Castlehill station in the Trelissick basin, Canterbury, and a bed of lignite overlying the marine beds of Miocene age within the watershed of the Upper Pareora, South Canterbury.

More doubtfully to the same period must be referred the lignites or inferior brown coals of the Hakateramea and Waitaki valleys, 45 to 50 miles inland from Oamaru.

There are also the thick deposits of fossil fuel occupying or found within the interior lake-basins of Central Otago, which have been generally referred to the Tertiary, sometimes to the late Tertiary, period; but the evidence is by no means clear that all the known occurrences of such should be so referred. Again there are, farther to the south, in the Taieri, Clutha, and Maitara valleys various and sometimes very thick deposits, in some places a mere lignite, in others a second or third-rate brown coal, which are usually considered as belonging to the Miocene period, but which, in more than one instance, will in the future have to be placed in the Cretaceo-Tertiary formation. There is even now no decisive evidence that the Maitara lignite near the railway-line opposite the township of that name is not of Cretaceo-Tertiary date, and it is certain, from the abundance of ambrite (derived from a coniferous tree closely allied to the Kauri of the North Island, but which has long since disappeared from the South Island) occurring in the deposit, that the vegetable matter composing it differed but little from that which formed the coal-seams of Green Island and Shag Point. The same remarks will apply, and with even

greater force, to the country north-west of Mātaura, and flanking the Hōkonui hills within the watershed of the Makarewa stream.

Exceedingly modern-looking deposits of lignite are found along the eastern shore of New Harbour, between Invercargill and the Bluff, but the very modern date which has been assigned to these deposits rests on no further authority than the but slightly compressed condition (comparatively speaking) and inferior quality of the lignite.

The brown-coal formation farther to the north-west at the Nightcaps, Morley Creek, and Centre Hill, there can scarcely be any question, belongs to the Cretaceous-Tertiary period; but there are farther deposits more to the west, and on the coast-line towards Riverton and Orepuki, respecting the age of which there may justly be a difference of opinion, as the geology of this district has been worked out in the light of recent discoveries.

But, besides in these localities named, it has been contended that the North Island coals wholly, and those of Nelson and the west coast of the South Island in part (excepting the bituminous coals), together with all the coals of the east coast, saving those found in the Malvern Hills (Canterbury), at Shag Point (Otago), and at Mount Hamilton (in the Southland district), should all be referred, not to the Secondary epoch, nor to a Cretaceous-Tertiary formation, but to some part of the Tertiary period.

Practically, it matters not whether we consider our coal-fields to be Tertiary or Cretaceous, as regards the period when the coal-seams were deposited; but it is of the very greatest importance whether they belong to one or two or more periods, and it is this that, under guise of a controversy as to the age and nomenclature of the beds, is the point at issue, and it is to prove the identity of the principal coal-formations of the colony that the Geological Survey has laboured during the past fifteen years. Indeed, so far as my own views on the subject are concerned, they have ever been what they are now—that we must regard all the great coal-deposits of New Zealand as belonging to one sequence of strata, or otherwise involve any systematic consideration of them in inextricable difficulty.”*

For convenience of classification and reference, the coals of New Zealand have been divided by Sir Jas. Hector as follows:—

I.—Hydrous (coal containing 10 to 20 per cent. of permanent water).

- (a) *Lignite*.—Shows distinct woody structure, laminated, or shows that structure on desiccation; very absorbent of water.
- (b) *Brown Coal*.—Rarely shows vegetable structure. Fracture irregular, conchoidal, with incipient lamination; colour, dark brown; lustre, feeble; cracks readily on exposure to the atmosphere, losing 5 to 10 per cent. of water, which is not re-absorbed; burns slowly; contains resin in large masses.
- (c) *Pitch Coal*.—Structure compact; fracture smooth, conchoidal, jointed in large angular pieces; colour, brown or black; lustre, waxy; does not desiccate on exposure, nor is it absorbent of water; burns freely, and contains resin disseminated throughout its mass.

* Report of Geological Explorations during 1886-87. (Sir Jas. Hector, K.C.M.G., M.D., F.R.S., Director), pages xxxii-xxxiv.

II.—Anhydrous (coal containing less than 6 per cent. of water).

- (1) *Glance Coal*.—Non-caking, massive, compact or friable; fracture conchoidal, splintery; lustre, glistening or metallic; structure obviously laminated: colour, black; does not form a caking coke, but slightly adheres. This variety is chiefly brown coal altered by igneous rocks, and presents every intermediate stage from brown coal to anthracite.
- (2) *Semi-bituminous Coal*.—Compact, with laminae of bright and dull coal alternately; fracture, irregular; lustre, moderate; cokes moderately or is non-caking.
- (3) *Bituminous Coal*.—Much jointed, homogeneous, tender and friable; lustre, pitch-like, glistening, often iridescent; colour, black, with a purple hue: powder, brownish; cokes strongly, the best varieties forming a vitreous coke, with brilliant metallic lustre.

Although it is only the anhydrous coals which are of value for purposes of export, the pitch and brown coals, and even the lignites are, for local purposes, when their greater bulk is not an insuperable obstacle, very important factors in the prosperity of a district.

Bituminous coal is found almost exclusively on the west coast of the South Island, at the base of a great marine formation underlying limestone, clay, and sandstone. The whole series has a thickness of several thousand feet, and contains, wherever it is found in contact with the older rocks, which are much metamorphosed and of indeterminate age, valuable seams of coal. As in other parts of the world, the quality of the New Zealand seams appears to vary very much, according to the amount of disturbance and dislocation that they have suffered since their deposition. Thus the lignites and inferior brown coals are comparatively free from faults; the pitch coals and glance coals have been more disturbed, and the true coals have been in some cases subjected to great changes and dislocation.

Lignites occur in many places, principally in the South Island, where they are found occupying the ancient rock-basins. They contain large fragments of wood, sometimes almost indistinguishable from recent specimens, and although they burn slowly, and with a somewhat unpleasant odour, are of the greatest possible local value in the interior, where the great height above the sea renders the climate exceedingly rigorous, and timber exists either sparingly, or not at all. Deposits are also found in the Lower Waikato basin and near Raglan, both in Auckland Province, and in Wellington and North Canterbury.

Brown coal is widely distributed, and is found on the Waikato river in the province of Auckland, at Kaitangata in Otago, and also in Southland, as well as in considerable profusion in Canterbury.

Pitch coal, which is a really excellent fuel for local use, has been found at West Wanganui and Reefton in Nelson Province, at Shag Point in Otago, on the Waikato river, and at Wangaroa in Auckland, and also in Southland.

It will be hardly practicable to consider in detail the deposits of the colony in any other than their geographical order, commencing at the north.

2. GENERAL NOTES ON THE COAL-FIELDS.

NORTH ISLAND.

(1) *Auckland Coal-fields.*

The province of Auckland, which exhibits such a profusion of metalliferous ores, is but poorly provided with coal, for while the deposits are fairly numerous, the quality, except in the cases of Kawakawa and Hikurangi is inferior, and even in these two instances, it cannot be described as actually first-class. There are five districts; in the extreme north Wangaroa and Mongonui, next Kawakawa at the Bay of Islands, with Hikurangi between that area and the Whangarei field. Lastly Drury and Waikato, including Miranda.

The Wangaroa and Mongonui fields do not at present require notice, for although the coal at the former place is of fair quality, it has not been worked.

The Kawakawa coal-field is on a different footing, as the output has been largely used by ocean-going steamers. The pit is now on the eve of exhaustion. Plucky efforts have been made to discover either an extension of the seam, or fresh deposits, by the aid of the diamond drill, but to no effect, and the output has declined to 28,254 tons in 1891, raised by 70 men. The total since the commencement is 737,249 tons, in twenty-six years, during which time the concern can hardly be said to have been a commercial success.

The coal is brought to bank by an engine-plane, and the pumping is (or was, for the writer fancies it is now stopped) carried on by means of heavy pumping-gear in a shaft to the dip. The seam was originally 13 feet thick, but varies much, and the workings were pillar-and-stall. The roof is bad, and the slack very prone to spontaneous combustion. The port of shipment is 8 miles from the mine, and the produce is con-

veyed on a Government railway, which cost £86,283. The seam was originally found in 1868 by a person in search of Kauri gum, and it is a matter of deep regret that a good coal, worked by an enterprising company, under capable management, should not have brought a better reward. Two samples of the coal gave on analysis :—

		Per Cent.		Per Cent.
Fixed carbon	...	57.20	...	55.59
Hydrocarbons	...	36.00	...	38.10
Water	...	4.60	...	4.19
Ash	...	2.20	...	2.12
		100.00		100.00

The Hikurangi coal-field has been known for many years, but it was opened out only in 1890. In 1891, two mines were on the list, but as the railway was not then finished, the output had only a local sale, and was very limited. In fact, one mine put out nothing at all, and the other 576 tons. The pit in operation was worked by an adit and horse haulage, and employed no machinery. The seam is 6 to 11 feet thick, and gives the following analysis :—

		Per Cent.		Per Cent.
Fixed carbon	...	42.70	...	44.12
Hydrocarbons	...	44.46	...	46.89
Water	...	5.93	...	6.39
Ash	...	6.91	...	2.60
		100.00		100.00

The area of the field is stated to be 10 square miles, and no doubt when railway communication is established, the output will be considerable.

The Whangarei district has the advantage of a railway leading to a port from which the coal can be shipped, and has been worked for about twenty-eight years.

The Cretaceous-Tertiary rocks which lie unconformably on the slates, are much obscured by newer volcanic formations. Formerly two mines were at work, but one of these is now closed, and the Kamo mine has the whole trade. This concern put out in 1891, 15,652 tons, which was a decrease from the amount raised in former years: the reason appears to have been that during that year a creep extended over the workings, and caused a cessation of work.

The seam consists of a lustrous black coal, and is found to range up to 14 feet in thickness. A little explosive gas is found, and the slack takes fire spontaneously. The shaft is 240 feet deep, and the cage is fitted with safety catches and detaching hooks. The system employed in working is ~~hand and~~ pull. The analyses of a few samples are :—

	Per Cent.		Per Cent.		Per Cent.
Fixed carbon ...	52.63	...	49.08	...	50.01
Hydrocarbons ...	34.30	...	37.57	...	37.67
Water ...	8.91	...	9.24	...	9.01
Ash ...	4.16	...	4.11	...	2.69
	100.00	...	100.00	...	100.00

To the south of Auckland city, and situated both on the large river Waikato and on the railway which skirts it for so many miles, is the Waikato coal-field, which is likely in the future to play an important part in the commercial history of the colony.

The coal produced is clean-looking, black and lustrous, suitable either for household use or steam purposes. It is, however, of low specific gravity, and desiccates so rapidly on exposure to the air that it is useless for storage. In the mines it is subject to spontaneous combustion.

The seams were originally worked where they crop out on the banks of the Waikato river, and are found from 6 to 65 feet in thickness. In 1891, five mines were in operation, which yielded a total of 55,859 tons, and employed 164 men. This number includes the Miranda mine. Two are worked by shafts, the others by adit level. At the Taupiri Extended mine the shaft recently sunk was put down with considerable difficulty, as it was necessary to force down iron cylinders, which met with obstacles in the form of driftwood. Before the second shaft was sunk a circle of boreholes was made, to see if any similar obstruction existed. The cast-iron segments were then lowered, and the sand and drift removed by a dredge, without any water being pumped. The Taupiri Reserve mine, which turned out in 1891, 17,221 tons, worked under Lake Kimihia. By boring, the cover over the seam was found to be from 48 to 77 feet thick, mostly strong fireclay. The bords are 14 feet wide, and the pillars 21 feet, and of the 18 feet total thickness of the seam 5 feet is left for a roof. It thus appears that laterally 40 per cent. of the support is removed, and it is reasonable to suppose that by flaking of sides and driving of cross-cuts another 10 per cent. will be lost. This makes the spaces and pillars equal, which seems rather risky.

At Maramarua creek, near the Miranda Redoubt, a mine was for some time worked on a seam 54 feet in thickness, or even more, but it was closed in 1890, after a somewhat disastrous career. The output for that year was 228 tons and the total 20,668 tons. The pit was sunk on the edge of the Maramarua creek, a tributary of the Waikato river, and a canal costing £1,800 was cut to bring the coal to the main stream, by which it was brought down in punts to the railway siding at Mercer, where steam

cranes raised the boxes from the punts and emptied them into the railway trucks. The lease consists of about 1,000 acres, and the coal is of good quality; but the mine appears to have been injudiciously worked, or else it should have done better. Water, too, constituted a considerable drawback, and in 1887 it was necessary to draw water for 16 hours out of the 24. This work and the small sheaves which were used wore the winding rope out in two months. The following is an analysis of Waikato coal :—

					Per Cent.
Fixed carbon	...	...	...	...	47·08
Hydrocarbons	...	...	...	...	33·24
Water	...	...	...	...	17·60
Ash	...	...	...	...	2·08
					100·00

(2) *Mokau Coal-fields.*

In the Mokau district, which is situated at Taranaki, coal-seams have been known for upwards of fifty years, but the opening of the field was for many years retarded by the native ownership of the soil, and by the inaccessible position of the outcrops, which are on the Mokau river, 24 miles from its mouth, and far from railway communication. The tide ascends the river for about 24 miles, and small steamers carrying 25 to 100 tons go up to the mine. The coal is of fair quality, with the following composition :—

					Per Cent.
Fixed carbon	...	...	...	...	52·58
Hydrocarbons	...	...	...	...	31·67
Water	...	...	...	...	12·15
Ash	...	...	...	...	3·60
					100·00

but containing a good deal of sulphur.

The seam worked at the Mokau mine is 8 feet thick, with a band of shale in the centre, from 2 to 3 feet in thickness, but gradually decreasing as the seam is followed into the hill. Another mine, called the Co-operative, is stated to be in liquidation. In 1891 the two undertakings put out 3,713 tons.

Remarks on North Island Collieries.

Until population becomes sufficient to render the trade in Whangarei and Waikato coal much larger—and with these must be included the Hikurangi district, which is as yet hardly touched—the output from the North Island will be small. In 1891, the yield was 104,064 tons, or 15·5 per cent. of the total colonial output. This shows a decrease of 11,853

tons on the output for 1890, which was the largest annual production known. In 1878, the percentage of the whole colony was 36·3, but this proportion has almost uniformly declined ever since, owing to the superior quality of the fuel obtainable elsewhere.

SOUTH ISLAND.

Although the deposits of the North Island have proved of great benefit in the past, and will no doubt as settlement progresses become still more valuable in the future, it cannot be expected that by their aid any great export trade will be established. In the South Island, however, the case is different. On the west coast are seams, the produce of which can hold its own with that of any existing mines, and nothing is required but cheap methods of working and transport to enable these coals to compete successfully in the great markets of the world.

Before passing to these busy and successful centres it will be requisite to take a passing look at the coal-fields of the northern part of the South Island, the first of which is that of Picton.

(3) *Picton Coal-field.*

On account of its unrivalled harbour and geographical position, the presence of coal at this place caused great excitement and resulted in the formation of a company. Unfortunately the geological features of the locality were utterly unfavourable, for the coal exists, so far as is known, only in a triangular patch cut off by faults on all sides, and containing an area of about half a square mile. In all 700 tons of coal were raised, of excellent quality, but much faulted and crushed, and the works were soon abandoned, not, however, before a considerable sum of money had been lost in an undertaking, which, had the oft-repeated advice of the Geological Survey Department been followed, would never have been commenced. The analysis of the coal was as follows :—

					Per Cent.
Fixed carbon	...	...	...	...	63·21
Hydrocarbons	...	...	...	...	31·06
Water	...	...	...	...	4·32
Ash	...	...	...	...	1·41
					100·00

(4) *Collingwood and Takaka Coal-fields.*

A small coal-field exists at Takaka, on the shores of Golden bay, but it was for many years unworked, as the coal is of poor quality. The total output for 1891, when two mines (both opencast) were at work,

coal trade of the district—which contains some of the most valuable minerals found in New Zealand—is small and apparently stationary. In the northern portion of the field are some further outcrops which have received attention. The locality is known as Seaford, and the including strata are very much the same as those at Collingwood, that is to say, brown micaceous sandstones with pebble and grit-bands, all resting on a massive conglomerate. Two seams are known, the upper 2 feet in thickness, resting on a soft sandy clay, and the other as follows :—

							Ft. In.
Coal	...	...	...	...	...	...	0 8
Shale	...	...	...	...	...	...	0 6
Coal	...	...	...	...	...	...	2 0

As indicating to some extent the conditions of mining in this neighbourhood, it may be interesting to reproduce an estimate which was made in 1887 on the subject of working these seams :—*

						Cost per ton. s. d.
Capital, £10,000 at 7 per cent. interest =						
£700, on an output of, say, 28,000 tons						
per annum	...	...	...	...	...	0 6
Sinking fund, £500 per annum	...	...	...	...	...	0 4½
Royalty	...	...	...	...	...	0 3
Mining	...	...	...	...	...	6 0
Haulage	...	...	...	...	...	0 6
Outside labour	...	...	...	...	...	0 6
Inside „	...	...	...	...	...	1 6
Management	...	...	...	...	...	1 0
Cost of coal per ton on wharf	...	...	...	...	...	10 7½

The analyses of two samples of coal are :—

			Upper Seam		Lower Seam.
Fixed carbon	...	...	51·37	...	51·79
Hydrocarbons	...	...	39·72	...	36·18
Water	...	...	4·38	...	4·02
Ash	...	...	4·53	...	8·01
			100·00	...	100·00

(5) *West Coast Coal-fields.*

These actually extend, in broken masses, all the way from Collingwood to Jackson's Bay, but the first-named district has already been dealt with. The West Coast proper has two great coal-mining centres : Westport on the Buller river and Greymouth on the River Grey. A small outlying district at Reefton may also be referred to.

* Hector, *Report of Geological Explorations*, 1887-88, pages 12 and 13.

The Buller coal-field extends from the river of that name on the south, where the seams occur principally at an elevation of 1,800 to 3,000 feet above the sea, to the Mokihini river on the north, where they descend to sea-level. The only exceptions to the elevated position of the southern portion of the field are some detached masses of crushed and faulted coal occurring at the Waimangaroa and Ngakawau rivers. This is geologically interesting, but of small commercial value, as the product is so soft and incoherent as to be considerably lowered in value. Notwithstanding this defect, the Waimangaroa mines yielded 8,865 tons in 1891, but that at Ngakawau (which is owned by a Sydney, New South Wales, company) did not turn any coal at all, the reason given being that the seam has, in the dip, decreased in thickness to such an extent as to be unworkable. This seam was some years ago 16 to 18 feet in thickness, of which 8 feet was worked, the haulage being performed by a 6 inches double-cylinder engine. There is said to be a large area of high-level coal, to reach which will require very extensive and costly works. The pit was worked many years ago without profit, indeed at a very heavy loss, and remained idle for a long time, but has been recently revived by the Westport Ngakawan Coal Company, whose object was partly to make coke for shipment to New South Wales for the Broken Hill mines, and partly to erect smelting works at Westport, to which silver ore from New South Wales might be brought as return freight.

The writer is unaware to what extent these intentions have been carried out, but fears that the proposal to use New Zealand coke as fuel has not been a commercial success. This view is induced by the following extract from the annual statement for 1892 of the Minister of Mines for New Zealand (the Hon. R. J. Seddon, M.H.R.):—

In reference to our bituminous coal-fields, it is deplorable to see the waste of coal that is carried on at some of the mines. It will be recollected by some honorable members that when Mr. Kennedy, the managing director of the Hammer railway, was giving his evidence last year before the Gold-fields Committee on some of the measures of the Coal Mines Act which was passed last session, he stated that about 500 tons of slack was emptied into the Grey river every month from the Hammer mine alone, which ought to be utilized and converted into a marketable commodity. There is a large market for coke of good quality in the Australian colonies, and by a proper system of manufacture the slack from the mines on the West Coast would make the finest coke in the world. I called attention to this in my last statement, and the facts are fully borne out by the statements in a letter addressed to the Hon. John Lee, the treasurer of New South Wales, by the secretary of the Broken Hill Proprietary Company, which has been published. In this letter it is stated that the Broken Hill Company is using 1,000 tons of coke per week, but that all the colonial coke that has been tried is far inferior to that of either English or German manufacture, on account of the slack not being washed,

prepared, dressed, and burned, so as to make it more dense and hard. Colonial coke is found to contain about 6 per cent. more ash than English coke, and this is stated to be equal to using 80 tons more of the colonial than the English article every week, reducing the capacity of the furnaces by 70 tons of ore per week, and also necessitating 70 tons more flux being used for the same period, or, as the secretary states: "The use of colonial coke instead of English would mulct the company in the sum of £645 weekly, made up as follows: 80 tons at £5, £400; profit on 70 tons of ore at £2 10s. per ton, £175; 70 tons of flux-iron and lime, £70." The secretary to the company estimates the loss with English coke at 7 per cent., and colonial coke 13 per cent., while he states that most of the colonial coke can stand no burden, but crumbles up quickly in the furnace, and fills the space around the tuyeres with fine coke, causing large losses in lead and silver, both chemically and mechanically. He further states that they find it inferior to such a degree that its use to a great extent is entirely out of the question, and leaves no other course open to the company but to use either the English or Continental manufacture.

The whole of the blame must not in this case be borne by the New Zealand coals, for the New South Wales seams are exceedingly prolific in ash, as may be seen on reference to the papers by Messrs. G. Blake Walker and S. H. Cox.*

The Mokihinui coal-field, on the north, was many years ago the scene of an attempt to work, but the river is not a sufficiently good port for any large trade to be established, and it was only when the Government recognized the necessity of extending the railway from Ngakawau, a distance of 7 miles, that the future of the place began to look more bright. Two seams are known, one 23 feet thick, and the other less; in 1891 the output was 4,540 tons. The Mokihinui Coal Company has been to considerable expense, having spent, among other things, £25,000 on a railway from the port to their mine. This is comparatively useless until the connecting link with the Government line, which will cost £36,600, shall have been completed. The analysis of a sample of coal gives the following composition:—

	Per Cent.
Fixed carbon	56·01
Hydrocarbons	37·17
Water	2·60
Ash	4·22
	100·00

Coalbrookdale Colliery.—To the average British mining engineer this coal-field would perhaps be the most interesting in the colony, not only on account of the splendid quality and great thickness of the seams, but on account of the wonderful situation of the mine. Two thousand feet above the sea, on the top of a bald bleak plateau of coarse quartzose grit,

* *Trans. Fed. Inst.*, vol. ii., pages 268 and 321.

covered only by thick moss and scattered mountain scrub, and intersected by vertical ravines of enormous depth, round which the seams crop out, is a large and flourishing colliery village, with large hotels, a school of mines, library, offices of the miners' union, bakeries, stores, and schools. The history of the Westport Coal Company, Limited, who own this mine, offers an example, if not of rich returns and uninterrupted prosperity, at least of extraordinary persistence and perseverance in the face of great natural difficulties. Commenced about the beginning of 1878, several years elapsed before the works were in a state of completion. Bad weather, an excessively rough country, and numerous other obstacles retarded operations. Eventually coal was sent down, and then the prosperity, which was to have poured in, was for some time delayed by the defects in the Westport harbour, by the unsuitability of machinery, by faults and changes in the seams, and by a hundred other unforeseen sources of trouble and loss. In order to meet the difficulties it was agreed to write off a certain amount of the capital, and the concern now may be said to be doing moderately well. In January, 1892, the chairman stated that during the preceding ten years the company had worked 1,000,000 tons of coal, had expended £850,000, while the dividends paid had been £33,960, or a little less than 2 per cent. per annum on the capital. It is gratifying to note that for 1892 the profit was £22,048, which added to £6,368 brought forward from the previous year, was sufficient to pay a dividend and bonus amounting to about 10 per cent.

The existence of coal in this district was known to the early settlers, but nothing systematic was done until the year 1874, when a detailed topographical and geological survey was undertaken by the Government, and carried out at a cost of over £5,000. The result of this was to prove the existence of coal-seams over a large area, which is, however, very much cut up by enormous denudation. The deposits occur principally at an altitude of 1,800 to 3,000 feet; but towards the north, as has been mentioned, they come down to sea-level, and dip below it. The mapping of coal areas was unusually simple work, for numerous gullies and ravines caused the outcrops to be readily traceable. On receiving the reports of the Geological Survey Department the Colonial Government at once decided to proceed with the construction of a railway from Westport along the coast northwards to the Ngakawau river, a distance of nearly 19 miles, and also to improve the harbour, the average depth of which on the bar in 1870 AD was only 12½ feet. At the same time private enterprize was not dormant. Numerous leases were taken up, many by speculators without the means to work them. Finding, in 1877, that no effort was made to

develop the field, the Government took steps to force the hands of the lessees, in order that the ground taken up might be either worked or relinquished. Many of the leases were then amalgamated, and a new proprietary, known as the Westport Colliery Company, took over the leases and liabilities of several of the original holders, and guaranteed to spend in two years £10,000 and produce a minimum output of 20,000 tons. In August, 1880, coal was brought into the market, and since that date the works have been so energetically carried on that in 1892 working single shift no less than 198,000 tons was put out from the Coalbrookdale mine. This required a total of 302 men, which gives 637·7 tons per man, or counting the underground staff only (238 men), an output per man of 809 tons per annum. Unfortunately, there is no means of ascertaining on how many days the pit worked, but presuming this to have been five days per week, or 260 days, the daily output per man for a mine with exceptionally lengthy haulage would be 3 tons 2 cwts. 1 qr., or taking it at 4 days, 3 tons 17 cwts. 3 qrs.

Finding the original capital insufficient the company was some years ago re-formed, with a nominal capital of £400,000, and although the return has not been so great as the shareholders deserved, yet prosperous times seem now to have dawned. This is in great measure due to the increased depth of water on the harbour bar, which averaged 23 feet in 1892.

The coal is a free-burning, lustrous, fuel, good for steam or household use, and the following analysis shows its purity in a striking degree:—

	Per Cent.
Fixed carbon	63·81
Hydrocarbons	31·88
Water	3·08
Ash	1·23
	100·00

It is largely used for war vessels, and has great steaming power. The late Sir Jno. Coode, in his presidential address in 1889, before the Institution of Civil Engineers, said: "The bituminous coal found on the west coast of the South Island is declared by engineers . . . to be fully equal to, if not better than, the best descriptions from any part of the world. The wonderful escape of H.M.S. 'Calliope' during the hurricane at Samoa, when her engines were tried to the very uttermost, has been attributed by her captain and the people of New Zealand, apparently with good reason, to the superior quality of this coal, which was being used at the time."*

* *Proc. Inst. Civil Eng.*, vol. xcix., page 23.

The company owns two leases—one, the Coalbrookdale and Kawatiri of 2,479 acres, in which the present mines are worked ; and a new lease, as yet untouched, known as Granity Creek, and comprising 2,951 acres. The term is ninety-nine years, and the royalty 6d. per ton on large and small coal. The minimum rent merges in the royalty, but the company has a large dead rent to pay on the Granity Creek holding. Wages are high, and the men make a good deal of money. In 1889 the price for getting coal, large and small together, was 2s. 10d. per ton, and day wages were 10s.

The writer is unaware whether any important alterations have been recently introduced into the haulage arrangements of the Coalbrookdale colliery, but as a detailed account of the appliances at work in 1890 was published by Mr. T. J. Waters, F.R.G.S., managing engineer at that time,* a short abstract may be included.

The general system of mine haulage is endless-rope, which replaced an endless-chain formerly used and abandoned because of its frequent breakages, sometimes thirty in a day. The main plane is (these data refer to the early part of the year 1890) 1 mile 60 chains in length, and is worked by a $3\frac{1}{2}$ inches circumference plough steel-wire rope, of Lang lay, travelling at $2\frac{1}{2}$ miles an hour. The engine has one cylinder 20 inches in diameter by 48 inches stroke, and the driving wheel is 6 feet 8 inches in diameter, and lagged with cast-steel segments. The road varies much in gradient, the steepest being 1 in 10, and the difference in level is 90 feet against the load. Two branch systems are worked with separate engines, one known as the iron-bridge road, opening up the field to the south-east, is worked by a pair of 6 inches cylinder engines, and has a total grade of 146 feet against the load, with a maximum of 1 in 5. The Coalbrookdale section is worked by a single $6\frac{1}{2}$ inches cylinder engine, and runs in daylight up the bed of a creek, with the coal cropping out on each side, and numerous adits along its course. The rope travels at a speed of 1 mile per hour.

Chains are used instead of clips, which were difficult to accommodate to the curves and gradients. Mr. Waters designed a very useful arrangement (Figs. 1, 2, and 3, Plate III.,) for attaching the chain, by means of which the attendants are enabled to hang the tubs on as conveniently when the rope is moving as when it is at rest. His description of the arrangement is as follows:—"It consists of a short length of chain, on one end of which is welded a ring, and on the other a hook. At each hanging-on place a pair of light steel springs are bolted to a cross sleeper.

* *Proceedings of New Zealand and South Seas Exhibition Mining Conference, 1890, G. J. Binns, Hon. Sec.*

The loose ends of these springs are made to fit the rope and embrace it when pressed together. The hanger-on passes the chain three times round these springs where they embrace the rope, which slips between them as it runs, without imparting any motion to the chain clip; hence the hanger-on is enabled to pass the hook end through the ring on the chain, and make it fast to the truck at his leisure. At the proper time the truck is pushed forward a few inches by hand, when the chain-clip slips off the steel springs and holds fast on to the travelling-rope, drawing the truck with it."

The trucks are made of galvanized steel, 22 cubic feet in capacity, with cast-steel wheels of 24 inches gauge. The rails are 25 lbs. per yard on the full side, and 18 lbs. on the empty, with fished joints. The curve-rollers are of cast-steel 2 feet in diameter, placed at an angle of 30 degs. from the horizontal, so that the outside of the pulley is under the inner rail.

The surface-inclines are on a large scale and have been very successful. As the mine mouth is about 2,000 feet above the sea, gravity is sufficient to lower the output, but the country is of an excessively rough nature, and great expense was incurred in making a road to accommodate railway wagons containing $6\frac{1}{2}$ tons of coal, and having a gross load of 11 tons. The total length of the incline is $1\frac{1}{4}$ miles, and the fall 1,800 feet to the level of the railway at the foot of the hills. The upper incline—for there are two—is 33 chains long horizontally, with a drop of 834 feet in that distance; the maximum grade is 1 foot in 1 foot 4 inches. The drums are 10 feet 6 inches in diameter, with cranks keyed on to the ends of the shafts, and attached by connecting-rods to two 12 inches pistons working in cylinders fitted with cataract-governors. This is found to be infinitely superior to the hand brakes formerly used, giving a much greater approach to safety, and a longer life to the ropes used by nearly 100 per cent., besides which the hand-brakes repairs amounted to over £300 per annum. The lower incline is 50 chains long, with a drop of 864 feet and a maximum grade of 1 in 2. The time occupied in running is 2 minutes for the upper and $2\frac{1}{2}$ minutes for the lower section, but both are run simultaneously. The road is 3 feet 6 inches gauge, laid with 40 lbs. or 42 lbs. rails.

The Granity Creek inclines will be on the endless-rope principle, and are estimated to cost £50,000, which, with another £50,000 for rolling stock and opening up the mine, will make nearly a quarter of a million sterling spent in haulage and works. The mine tubs will come right down to the foot of the hill, and two inclines will be employed; the upper one 70 chains long with a fall of 700 feet, and the lower one 51 chains long with a fall of 960 feet. Hydraulic brakes will be employed. It is

expected that coal will come down about the end of the current year, and the total output from the mines worked by this Company at Westport will shortly be probably nearly half a million tons per annum.

About equidistant from Westport and Greymouth is the Reefton coal-field, situated on the Inangahua river. This area is limited in extent, and lies in patches on the upturned edges of the Maitai (Carboniferous) Slates. The coal is of very excellent quality, being in some cases bituminous.

The following analyses will give some idea of its quality :—

No.	Locality.	Nature of Coal.	Fixed Carbon.	Hydro-carbon.	Water.	Ash.
1.	New Durham Mine ...	Bituminous ...	54·09 ...	37·64 ...	4·36 ...	3·91
2.	" " ...	Brown ...	48·02 ...	35·57 ...	14·21 ...	2·20
3.	Lankey's Creek ...	Altered ...	58·01 ...	33·19 ...	6·79 ...	2·01
4.	Murray Creek ...	Bituminous ...	53·96 ...	35·87 ...	8·18 ...	1·99
5.	Dudley Mine ...	Brown ...	48·10 ...	35·88 ...	14·21 ...	1·81

During the year 1891, thirteen mines were at work, employing 20 men, and yielding 4,556 tons, most of which was consumed by the quartz-crushing machinery attached to the adjacent gold mines. The seams vary capriciously in thickness and dip.

Other outcrops are known in the Upper Buller district, but they have been only locally worked to a very small extent.

Greymouth District.—The next district to consider is the Greymouth coal-field, second in importance only to that of Westport, and while the seams at the latter place are mainly far above the sea, and are therefore worked level-free, those at the former lie to the dip, and are approached by shafts or dip drives. It is true that the Brunner coal-mine, which is the oldest in the district, and has furnished by far the largest output, was for many years worked above water-level, but the bulk of the field will undoubtedly require haulage.

The seams occur in grits and conglomerates, dipping in a westerly direction at 1 in 3, and the field is a good deal cut up by faults. The principal seam is 18 feet thick, and is exposed in the upper gorge of the Grey river, where it was originally worked and whence the coal was brought down the river in barges. At the present time the Government Railway, which is 8 miles in length, takes the output from the mines to the port of Greymouth, where there is a fairly good harbour.

At one time there were four mines, but they became merged into one company, and in 1892, for convenience in working, only two were open, viz., the Brunner and the Coalpit Heath, which are practically one mine.

The Brunner colliery has been at work twenty-nine years, and had yielded to the end of 1891, 868,072 tons. The workings in 1891, when the output was 75,729 tons were confined chiefly to the extraction of pillars, and the ventilation was produced by a Schiele fan, a 16 feet Guibal fan formerly employed having proved insufficient. The engine-plane is fitted with a pair of 14 inches cylinder engines with 18 inches stroke, and an electric haulage-plant is in operation, but of this latter the writer has no details. There is also a rope-driven pump with a pair of 9 inches by 24 inches double-acting rams which raises the water 170 feet. The surface-works comprise a large brick and tile plant, where very excellent firebricks and gas retorts are manufactured, which find a ready sale not only in New Zealand but in Australia.

A slack-washing and briquette plant has been erected, and it was intended to use the bye-products of the coke in the manufacture of briquettes, which are also made by the company at Christchurch on the east coast. In the early part of 1892, the demand for this class of fuel was stated to be very brisk, and the output, which was then 6 tons per day, was said to be finding a ready sale.

In 1889, a committee of the House of Representatives took evidence on these mines, and among other details the following facts were elicited:—The average number of days worked was $3\frac{1}{2}$ to 4 per week, and the minimum wage was 12s. per day.

The Coalpit Heath colliery, which was originally in private hands, has now become the property of the Grey Valley Coal Company, Limited, half of which belongs to the Westport Coal Company, Limited. The workings lie to the dip of the Brunner colliery, and the coal is raised by the hauling-engine attached to that mine. At one time a rectangular shaft measuring 10 feet by 6 feet and 280 feet deep was used with a single (18 inches by 8 feet) cylinder engine. But the whole arrangement was crude and inconvenient. The seam is 18 feet in thickness, and of excellent quality. The workings were laid out on the bord-and-pillar system, and the pillars have to a great extent been removed. In 1891, the output was 69,592 tons, and since the commencement 429,991 tons have been raised. The workings are ventilated by a Schiele fan, and the pumping appears to be heavy, as there are on the published list no less than seven engines for this purpose varying from 10 inches ram and 4 feet stroke, to 4 inches ram and 12 inches stroke.

On the opposite side of the river to the Coalpit Heath mine is the Greymouth Wallsend colliery, now standing. It is a matter of great regret that this pit should have been set down, as it is no doubt the most

advanced example of mining in the colony. The shafts are circular, 11 feet and 14 feet in diameter. The downcast, which was sunk in 1885, was lined for some distance with concrete blocks, grouted in with cement, instead of with cast-iron tubing.* The winding-engine consists of a pair of 30 inches cylinders with 60 inches stroke working a 16 feet cylindrical drum fitted with steam brake and steam starting-gear. The boilers are of steel, 30 feet by 7 feet, and of the Lancashire type, working at 60 lbs. pressure; head gear of iron, lattice girders 68 feet to centre of pulleys, which are 14 feet in diameter. A 30 feet Guibal fan airs the workings, and there is a small air-compressing engine for rock drills. The last output appears to have been raised in 1890, when 26,690 tons was the amount. Altogether only 205,539 tons has been raised from this fine pit, a large proportion of which must be credited to a small engine which worked a single shaft many years ago. When the coal trade expands, this property will be able to assume a worthy position.

A small pit known as the Tyneside colliery, to the rise of the Greymouth Wallsend, has been abandoned for some years.

Farther up the Grey river, and some distance from it on the north side, is the Blackball colliery belonging to a company recently floated on the London market; there are two seams 4 feet 6 inches and 12 feet thick respectively, and a cross-measures drift 1,232 feet long has been constructed to cut them. In 1891, only 30 tons of coal was produced, but the works are not yet connected with the railway. In a colonial newspaper of recent date, the company is stated to be making fair progress with an aerial tramway, presumably for the purpose of carrying the coal across the Grey river. A bridge 47 chains in length was originally proposed for this purpose, but the former method seems to have been preferred; the first cost will no doubt be less, but whether it will prove an economical method for the purpose is a matter of opinion.

The following average analyses of Greymouth coal may be given:—

		Per Cent.		Per Cent.		Per Cent.		Per Cent.
Fixed carbon	...	53·25	...	53·50	...	59·38	...	53·08
Hydrocarbons	...	38·73	...	41·28	...	34·48	...	41·95
Water	...	1·48	...	1·41	...	1·05	...	·99
Ash	...	6·45	...	3·81	...	4·09	...	3·98
		100·00		100·00		100·00		100·00

On comparing these figures with the previously given analyses of the Westport coal, it will be seen that the latter contains less ash, and is

* "Coal-mining in New Zealand," by G. J. Binns, *Trans. N.E. Inst.*, vol. xxxv., page 194.

poorer in hydrocarbons. On account of its richness in the latter respect the Greymouth coal has been largely used for gas-making, and for many years it commanded 7s. to 8s. per ton more than that from Newcastle, New South Wales, but a very good gas-coal was recently found at Stockton, New South Wales, which ousted the Greymouth coal from the Australian markets.

A yet undeveloped coal-field occurs at Point Elizabeth, on the sea coast, a few miles north of the Grey river. The harbour at that place is variously stated as being the best in New Zealand, and as being utterly unsafe. The writer has no personal knowledge of the locality.

Owing to the uncertainty of the harbour at Greymouth the pits work very irregularly, not, it is stated, averaging 4 days per week. Mr. M. Kennedy, managing director of the Grey Valley Coal Company, recently stated that 12s. was the minimum earnings for a day of 7 hours.

After leaving Greymouth the known areas of coal on the West Coast are scattered and comparatively small. Near Hokitika an attempt was made to work some thin seams, but without success, and in the neighbourhood of the Haast river outcrops are found, but in such a rough and inaccessible position that any prospect of working them is remote.

(6) *Canterbury Coal-fields.*

Although, as has been stated, the West Coast coal-fields alone supply coal of first-class quality, there is much fuel of a valuable nature to be found on the eastern side of the great axial range of mountains known as the Southern Alps.

In the Province of Canterbury the principal development in this direction has been in the Malvern district, where the following four classes of coal are found:—

1. Anthracite.
2. Altered brown coals, in which the percentage of water is not high.
3. Altered brown coals in which the percentage of water is high.
4. Brown coals.

The working of the first class is confined to a small pit, whence the supply for a sheep station is obtained, and the output from which has averaged only 10 tons per annum since the pit started, the return for 1891 being *nil*. The locality is geologically interesting as the anthracitic quality of the coal is directly traceable to a dolerite flow, which overlies the seam. The analyses given vary very much, fixed carbon being returned as constituting from 65·8 to 88·91 per cent. of the total, and ash up to 24·25 per cent.

Of the second class the output has ceased, as the seams formerly worked dipped at very high angles, and were soon exhausted to water-level, below which it did not pay to follow them. The analysis shows:—

					Per Cent.
Fixed carbon	...	...	...	...	53.29
Hydrocarbons	...	...	...	...	32.04
Water	...	...	...	...	12.65
Ash	...	...	...	...	2.02
					100.00

but the composition probably varies very much.

Of the third class, a little has been raised for the requirements of a sheep station.

The brown coals which constitute the fourth class were at one time largely mined, but the trade seems to have greatly fallen off, and in 1891 the production was only 11,710 tons from 6 mines, whereas in 1884 it was more than double. The following analyses of the Springfield coal may serve as an example of the quality:—

		Per Cent.		Per Cent.		Per Cent.		Per Cent.
Fixed carbon	...	47.90	...	50.60	...	55.50	...	63.20
Hydrocarbons	...	41.80	...	38.80	...	30.90	...	23.60
Water	...	6.30	...	7.80	...	4.20	...	3.20
Ash	...	4.00	...	2.80	...	9.40	...	10.00
		100.00			100.00			100.00

Though there are in the southern portion of Canterbury sundry small mines, none of them merit much attention, and it must be allowed that the mineral resources of this province are but poor. Fortunately, the natural agricultural advantages are so great as to amply compensate for mineral poverty, and a judicious and elaborate irrigation scheme has materially assisted agriculture.

(7) *Otago Coal-fields.*

There were in Otago, in 1891, no less than 80 coal-mines on the official list, of which 20 did not produce, or at any rate were not returned as producing, any coal. The total yield was 164,870 tons, or 11,558 tons less than in the preceding year, but of this total 110,042 tons came from 5 mines, leaving 54,828 tons, or an average of 731 tons each for the remaining 55 working pits. Many of these are mere opencast excavations, into which carts are driven, and where the fuel is got as cheaply as it is probably possible for it to be obtained under any circumstances.

There are, however, several collieries which have attained an output of more respectable dimensions, and at which the appliances are of a

superior character. Continuing the southward course adopted, the first of these is Shag Point colliery, situated on the seashore, about 40 miles north of the city of Dunedin, and close to the main line of railway, with which it is connected by a short branch. The coal is of very excellent quality, for a pitch coal, and has the following percentage composition:—

				A	B
				Per Cent.	Per Cent.
Fixed carbon	...	...		51·38	55·00
Hydrocarbons	...	...		22·78	24·83
Water	...	...		19·92	13·89
Ash	...	...		5·69	6·28
				99·77	100·00

The measures dip E.S.E., at 10 degs., below the sea, where they have been explored to a small extent, and where in all probability a very large area exists. Rising to the west they form an anticlinal arch, which is terminated westward by a syncline, from the base of which they again rise, at high angles, into the hill known as Puke Ivitai. In 1880, the output was 36,066 tons, but it has since considerably fallen off, and in 1891, only 7,814 tons was raised, making 4,298 tons less than the preceding year, and a total of 228,242 tons since the opening of the workings. Two seams are mined, with a thickness varying in one case from 2 to 12 feet, and in the other from 1 foot to 4 feet. The output is raised partly by a shaft measuring 16 feet 6 inches by 6 feet and 200 feet deep—(lately, the writer believes, this has been deepened)—and the water in tanks which automatically fill and empty themselves. The workings are free from gas, but the slack is remarkably subject to spontaneous combustion, and great trouble and expense have resulted from this fact. The roof also is very bad.

In the same district, but in the trough of the syncline to which reference has been made, is the Allandale coal-mine, commenced about the year 1887. This seems already to have outstripped the older mine in output, for in 1891, the production was 10,735 tons. The seam is 7 feet in maximum thickness, and is worked by a dip drive, up which a small fixed engine draws the wagons. By now the pit-mouth is, presumably, connected with the railway by a tram road.

The extension of the coal-measures beneath the Palmerston flat is a matter of conjecture, but it is to be hoped that this may prove to be the case, for the coal at this locality is of good quality and the situation favourable.

No further important deposit is known until the city of Dunedin is passed, about 6 miles from which centre, on the main south line, is the

Green Island coal-field. The coal here produced is of inferior quality, but the seam (only one is worked) is 19 feet thick, and the measures consist of sands, clays, ferruginous gravels, shales, and fireclays, resting unconformably upon the upturned edges of highly metamorphosed rocks of unknown age, and dipping to the north-east at an angle of 1 in 10 beneath a thick sandstone of Tertiary age, which is again overlain by the volcanic rocks of the Dunedin basin.

The field has been opened for about thirty-three years, and very numerous pits have been commenced, many of which have been lost owing to spontaneous fires, which are very rife. The tenure of the land is freehold, and the royalty usually 1s. per ton. A very large proportion of the seam is lost, as only 7 feet to 8 feet is worked in the first place by the room-and-rance system, and 3 feet more is got in coming back. In 1891, eight mines were at work, employing 138 men, who turned out 50,818 tons, a considerable amount less than the output in some former years.

Of these eight mines only three were connected with the railway, and one (Abbotsroyst colliery) has private telephonic communication with Dunedin. The produce of this field has, when first got, a lustrous appearance and dark brown colour, but desiccates rapidly on exposure to the air. It burns freely with a slightly unpleasant smell, and leaves a bulky incandescent ash. Notwithstanding these defects, it is a fairly popular second-rate fuel in and about Dunedin.

The mines are entirely free from explosive gas, and accidents of any kind are rare.

The analyses are as follows:—

			Per Cent.		Per Cent.		Per Cent.
Fixed carbon...	...	...	40.84	...	36.00	...	35.70
Hydrocarbons	...	...	36.57	...	42.50	...	39.80
Water...	...	...	18.67	...	19.00	...	23.10
Ash	...	...	3.92	...	0.90	...	1.40
			100.00	...	98.40	...	100.00
Sulphur	...	...	...	...	0.90	...	3.66

The Clutha coal-field, which next comes under consideration, is of large area, extending from the Clutha river on the south to 9 miles north of the Tokomariro river, a distance of 20 miles.

The formation consists of conglomerates, sandstones, clays, and shales, with coal-seams, forming ranges of hills 700 feet high in the neighbourhood of Kaitangata, and of less altitude to the north where they rise again on the flanks of Mount Misery, which is composed of schists.

The first mine was opened in 1858, and although enjoying the advantage of financial assistance from the Provincial Government, was not a success.

In 1891, thirteen mines were at work, but if the output from the Kaitangata Railway and Coal Company's mine (58,945 tons) be deducted, the remainder is under 10,000 tons. The mine belonging to this company is a good example of a successfully-managed Colonial colliery, at which the coal is by no means first-class, but the working of which has been for many years highly profitable. Originally two companies held rival interests, but in 1880 the Kaitangata Railway and Coal Company bought out the neighbouring proprietors, and have since worked the whole area.

The workable seams are four in number, the uppermost 3 feet 6 inches in thickness, and about 250 feet below this is a 9 feet seam which has not been worked. At a further depth of 250 feet is the main seam, upwards of 35 feet in thickness. From the small seam about 7,000 tons was taken in 1876-77, but it has been for many years abandoned. About 150 feet below the main seam is another, 19 feet in thickness, which was discovered by chance in 1889, but this enterprising company would appear not to be contented with even these quantities of coal, for the recent Dunedin papers state that they have purchased a diamond drill, capable of boring 2,000 feet, in order to prove the lower measures. The main seam is a good deal broken, and in places highly inclined; the roof is a hard quartzose conglomerate, 70 feet thick, and auriferous, though not sufficiently so to be workable. The floor is moderately hard. In the original mine the seam dipped at 1 in 7, and on approaching the dip took a plunge at 45 degs. Inclines were driven on the full angle and levels on the strike close to the roof; from these levels bords were driven to the floor. These workings eventually were closed, owing to a very heavy weight which came on. In the flat portion of the lease, the system was ordinary bord-and-pillar. About 8 feet of coal was got at first, and afterwards as much of the top coal as possible. It will readily be understood that during this operation the working-places were of enormous height, and hence some change became necessary, when the following system was tried. At the first operation about 10 feet vertically was taken, and sufficient laterally to bring on a weight which crushed the pillars into the floor; the whole area was allowed to settle, and the upper portion of the already partially-worked bords was then taken out. Of course, an enormous proportion of the seam was sacrificed by this system, but this appears unavoidable in cases of so thick a deposit. The coal is raised by an engine-plane 1,076 feet long and 9 feet wide by 6 feet 6 inches high, dipping 1 in 5 through the conglomerate and measures. This road, which is very hard in places, and in which some water was met with, was constructed by means of rock drills driven by compressed air, in six months.

The seam gives off some explosive gas, and the slack ignites very readily. In a paper read in 1890, Mr. Shore, the manager, gives some interesting details on this point, one of which may be reproduced :—

A few years ago an incident occurred having a remarkable bearing on the rapid generation of spontaneous combustion under favourable circumstances. Pending the erection of air-compressing machinery, steam was temporarily conveyed along a dip tunnel for pumping purposes: 3 inches pipes enclosed in a 12 inches by 12 inches wooden box filled with sand were used. The loaded trucks by accident left the tram rails. Anxious to get operations started, the men turned one of the trucks, loaded with wet dross, over on top of the box containing the steam-pipe. The temperature of the tunnel, which was used as an up-cast, was 74 degs. Fahr. Twenty-two hours from being turned over the truck was found to be on fire. When removing the truck the dross (about 7 cwt.) had the appearance of newly-prepared asphalt.

The machinery at this mine is very complete, and the following may be given as an example of what is used. In 1886, the shaft-engines which were used only for drawing water, consisted of a pair of 9 inches by 14 inches cylinders, while the coal was raised by a pair of 9 inches by 12 inches engines geared to a 12 feet drum. In case of accident to this engine, the haulage could be carried on by a single 20 inches by 54 inches engine used for compressing air in an 18 inches cylinder. From this compressor, at that date, two Tangye pumps were worked, one 1,300 feet distant, and the other 1,000 feet. In the mine was a pair of 12 inches by 24 inches hauling-engines, also to be worked by compressed air, if required. A Harrison coal-cutter had been tried, but the writer believes that it has not been subsequently much used. Since that date the company appear to have been extending their operations, for so lately as February 9th, 1893, a notice appeared in the Dunedin papers of the purchase of a compressed-air pumping-engine, manufactured in that city by Messrs. A. & T. Burt. This engine seems, from the description, to consist of a 20 inches air cylinder with 24 inches stroke, coupled tandem on to a double-acting 5½ inches ram, and is to deliver 10,000 gallons per hour to a vertical height of 700 feet. It appears that this would give a somewhat excessive speed, but probably a pair of rams are used. The purchase of this pump has been necessitated by the deepening of the shaft which has been continued from 400 feet to 700 feet. In 1891, the output was 58,945 tons, and the undertaking has produced 629,051 tons in fifteen years. The means of transport is furnished by a private railway 4 miles in length, on which the company spent £26,000, and the bulk of the coal is sold in Dunedin, which is about 50 miles distant from the pit's mouth, where it is a great favourite. It is black and glossy, with a conchoidal fracture and clean to the touch; it burns freely with a cheerful

blaze, forming a hot fire, and leaving a bulky incandescent ash. The following analyses were made in 1890 by the writer after the coal had been for some time exposed to the atmosphere:—

		A.		B.		C.
		Per Cent.		Per Cent.		Per Cent.
Fixed carbon	...	41·96	...	39·42	...	41·47
Hydrocarbons	...	35·49	...	39·01	...	37·28
Water	...	15·85	...	16·71	...	17·48
Ash	...	6·69	...	4·76	...	3·76
		99·99		99·99		99·99
Sulphur	...	0·838	...	1·141	...	1·071

In addition to the property described above, the company owns a freehold coal-bearing estate of 2,200 acres near Tokomariro, 41 miles from Dunedin.

The working of the Kaitangata colliery has been for many years very free from accident, but in 1879, before the enforcement of mining regulations by Government, a disastrous explosion occurred, which killed 3 persons, and left the 31 remaining in the mine to die of after-damp. In a few weeks the sum of £15,378 was subscribed in the colony for the benefit of the widows and orphans, £10,000 of this sum being raised in Otago alone. In the beginning of 1890, £14,631 had been paid in direct alimony and £563 in expenses; and notwithstanding this large disbursement, there was £11,645 left to the credit of the fund. The writer gathers from the Colonial newspapers that legislative action has been taken, and that the capital has been placed in the hands of trustees as a fund for general mining accidents.

Near the Kaitangata Railway and Coal Company's mine, a company known as the Castle Hill Coal-mining Company has of late years been engaged in sinking a shaft. Some time ago a borehole proved the coal at 400 feet, and a small shaft was put down, striking a good seam. Since then a 13 feet circular shaft has been commenced, which was to cut the coal at 600 feet. Brickworks were established and a railway built to connect with the existing private line. Unfortunately a great deal of water and running sand was met with, which overpowered the pumping appliances, and when the sinking was resumed, after standing for some time, the sides were found to be damaged. Information under date February, 1893, is to the effect that the shaft is abandoned, and the workings will be approached by a cross-measure drift dipping 1 in 4½.

Scattered throughout the interior of Otago are numerous small mines, many of them openwork, and employing only a man or two for a short time.

(8) *Southland Coal-fields.*

The coal-fields situated in the province of Southland are mostly only of local importance. Exception to this may perhaps be made in favour of the Nightcaps Coal Company's freehold mines which produced 14,485 tons in 1891. There appear to be three separate mines close together, working seams varying from 8 feet to 15 feet in thickness and employing 33 men. The fuel is bright, black, clean-looking, burning well and containing—at any rate as regards one seam—much fossil resin. The analysis is as follows:—

	Per Cent.
Fixed carbon	47·81
Hydrocarbons	21·04
Water	29·24
Ash	1·91
	100·00

3. METHODS OF WORKING.

The almost universal system of working is by bord-and-pillar, or the Scottish room-and-rance, which is very similar. Generally the pillars are left much too small, but sometimes the plan is properly laid out and a fair proportion recovered. The roofs vary very much: on the western coast of the South Island, hard gritty rock; in the Kaitangata mines, hard coarse conglomerate; at Kawakawa, sandstone; in the Waikato and in many of the brown-coal-mines, running sand.

There are on the official list 161 coal-mines, but of these 20 are dormant, and the remaining 141 may be classified as below. In some parts of the official reports two or more pits are occasionally grouped, which accounts for the discrepancy noticeable between this table and that given on page 73.

Worked by shafts—					
Steam-power used	8				
Horse-power used	6				
Hand-power used	2				
Total worked by shafts	16				
Worked by adits—					
Engine-power used	17				
Horse-power used	25				
Hand-power used	31				
Not stated	4				
Total worked by adits	77				
Opencast	42				
Method not stated	6				
Total	141				

4. MACHINERY.

Of the New Zealand coal-mines, only twenty-five in 1891 utilized engine-power for raising the mineral, and this is accounted for by the fact that so much outcrop coal is found level-free, and at present horse or hand-power is usually found sufficient. In a few cases good winding and hauling-engines are employed. As regards ventilation, it appears that there are three fans, five furnaces, one steam-jet, one steam-jet and furnace combined, while two mines owe their ventilation to steam-pipes in the upcast shaft. Compressed air is occasionally, but seldom, employed; electricity as a motive power in the one case already noted. Electric signals are common. A Harrison coal-cutter was tried at Kaitangata, where also power rock-drills were very successfully introduced. Mechanical stokers were tried at Greymouth and abandoned. Telephones are very largely utilized.

5. LEGISLATION.

In many respects the law for regulating collieries in New Zealand (The Coal-mines Act, 1891) is similar to that at present in force in Great Britain, but as the minerals are in almost every case Crown property, the subject of leases forms a not unimportant portion. The valuable coal-fields of Westport and Greymouth are under the control of the Harbour Boards established for these places, and although leases may be granted by the Minister of Mines, the application must first come before the local body interested, and (apparently to guard against a monopoly) any proposed amalgamation of leases may be vetoed by the Legislative Assembly.

The following are, shortly stated, the usual terms of lease. (1) Term not to exceed sixty-six years; (2) area not to exceed 2,000 acres, and dead rent to be not less than 1s. or more than 5s. per acre; (3) royalty to be not less than 3d. or more than 1s. per ton on all coal raised; (4) when the royalty exceeds the dead rent, the latter ceases; (5) no wayleave or surface rent is paid, but only such surface as is actually required shall be taken; (6) any person requiring "free access, egress, and regress" upon the land leased for the purpose of constructing any adit or tunnel, shall have power to do so, on obtaining the sanction of the Minister of Mines (on the recommendation of a Warden or Commissioner of Crown Lands), but coal-mining is not to be interfered with; (7) all timber required for mining purposes may be cut, but otherwise timber on leases is reserved to the Crown; (8) all minerals other than coal are excepted; (9) power is reserved to the Crown to resume possession on paying compensation; (10) in case of neglect on the part of lessees to work during three

months, notice may be given to resume: if this be neglected for an additional three months, the lease may be determined, and "the Queen, the Governor, or the Minister may enter on the demised premises and take possession of all buildings and improvements thereon." The next clause, however, states that the lessee shall be allowed two months to remove plant, but not buildings. (11) If at any time "the lessee neglects or refuses to pump the water out of any underground working for three days after the inspector has given the lessee notice in writing to do so, the inspector may, if it shall appear that such neglect or refusal to pump the water is likely to be prejudicial to the safety of any adjoining mines, or to the prejudice of the Crown, as proprietor, enter upon the mine and take possession of the pumping machinery, and employ men to work such machinery for pumping out the said workings, at the cost of the lessee; and any costs so incurred shall be deemed a debt due to Her Majesty by the lessee." (12) The lessee is bound, if so required, when the mine is being worked, to supply the Government, or any private railways, or any steamships with coal at current rates, each railway or vessel with not more than seven days' supply—strikes excepted.

Inspectors are to be appointed, every one of whom is to be the holder of a first-class certificate, and the clauses relating to the appointment of managers are similar to those in the British Act.

A board of examiners is appointed by the Government, and the examination fee is £1, which enables the candidate, in case of failure, to have a second try, within three months. The questions set by the examiners are reasonably easy (see Appendix A). There are two grades of certificates, three in fact, as in case of a mine employing six men or less, a "permit from the inspector" is required. Not only for managers are certificates requisite, but also for engine-drivers, who raise men either in a shaft or plane. Due provision is made for certificates of service in both cases. "Any person of good repute producing a certificate of competency from any duly constituted and recognized authority outside the colony" can obtain a certificate either as manager or engine-driver.

No female and no boy (that is, under 13) shall be employed in or about any mine, and the next section enacts that "no boy or youth (that is, under 18) shall be employed for more than forty-eight hours in any one week, exclusive of the time allowed for meals, or more than eight hours in any one day, except in cases of emergency. But no person shall be deemed guilty of an offence against this Act for a contravention of that part of this section relating to the time for which persons shall

not be employed below-ground, if he prove before any two justices, not being interested in any mine in which such person or persons are employed, that there were special circumstances to render such contravention necessary for the proper working of the mine; and that such contravention was not injurious to the workmen employed in the mine."

Section 29 enacts that no person under 18 is to have charge of an engine used for lowering or raising persons, but this is somewhat superfluous, as General Rule 21 forbids any person under 21 to have charge of any steam-engine or boiler used in the working of any mine.

No person in charge of steam machinery shall work for more than eight consecutive hours, exclusive of the time used in raising or exhausting steam and of meal times, and of "any time in which such person is employed in case of breakage or other emergency."

Section 31 provides for the usual registers of "boys employed in connexion with the mine," but as section 27 directly prohibits the employment of any boy "in any capacity," these registers will not be largely used, and the numerous references to this class of labour might well have been left out.

Section 32 contains the General Rules, which are prefaced by the "reasonably practicable" clause.

General Rule 1 defines the "adequate amount of ventilation to be not less than 100 feet of pure air per minute for each man and youth, and horse, pony, donkey, or mule, which shall sweep undiminished along the airway through each working-place."

By General Rule 15 cage covers are defined as "constructed of iron not less than one quarter part of an inch thick, and shall be securely hung on hinges and fitted with sloping sides, so as to be readily lifted upwards by persons within the cage."

General Rule 20 requires ropes and chains to be tested "to carry twice the weight of the ordinary load" before being used, and also, where men are raised and lowered, a similar test is to be applied once in every three months.

Boilers have, according to General Rule 32, to be subjected to a hydraulic test once in every six months. It may be mentioned that inspectors under "The Inspection of Machinery Act, 1882," make regular examinations of all steam-boilers, and grant a certificate, beyond the pressure stated on which the boiler is not to be worked. A charge is made for this certificate, exceeding—(the writer speaks from memory)—very considerably the premium paid in England by boiler-insurance companies for examination and insurance.

In mines liable, "in the opinion of an inspector," to an inundation or inburst of water, such escape roads as may be prescribed by the Minister of Mines are to be constructed, and also provision for the safety of the men during the period of any inundation or inburst of water in such mine.

General Rule 41 contains the "two hours before commencing work" examination clause.

General Rule 44.—All safety-lamps are to be of a pattern approved by the inspector.

Special rules are not framed as in Great Britain, but are contained in an appendix to the Act. There is, however, power for framing any additional rules which may be advisable.

Section 44.—It is compulsory on the inspector to immediately investigate any complaint from a miner.

Section 45.—Every mine where there are underground workings—(N.B.—In 1891 there were ten mines on the list, all with underground workings, and furnishing a total output of 369 tons, or under 37 tons each per annum)—is required to keep a plan, which must be made up every six months by a certificated manager, a duly-qualified mining engineer, or a surveyor authorized as such by the Surveyor-General. A copy to be sent to the inspector, who may, if he thinks fit, have a check-survey made, and if the original plan should prove to be incorrect the inspector can recover the cost of the check. Power is reserved for the cancellation or suspension of certificates.

Section 52 provides that "Any accident occurring in a mine shall be *prima facie* evidence that such accident occurred through some negligence on the part of the owner."

Section 53 provides for compensation of employes injured through non-observance of the Act, and may best be given *in extenso*:—"If any person employed in or about any mine suffer any injury in person, or be killed, owing to the non-observance in such mine of any of the provisions of this Act, such non-observance not being solely due to the negligence of the person so injured or killed, or owing in any way to the negligence of the owner of such mine, his agents or servants; the person so injured, or his personal representatives, or the personal representatives of the person so killed, may recover from the owner compensation by way of damages as for a tort committed by such owner; and the amount of such compensation with the costs of recovering the same when determined, shall constitute a charge on the mine and mining plant, in or about which such person was so employed, and all charges arising under the provisions of this section shall, as between themselves, be paid rateably.

Such compensation may be recovered under the provisions of 'The Deaths by Accident Compensation Act, 1880,' or 'The Employers' Liability Act, 1882,' which shall respectively be applicable, according to the circumstances of each particular case; subject, however, that notice of injury having been sustained may be given under the last-mentioned Act at any time within three months from the occurrence of the accident causing the injury, instead of within six weeks as in the said Act mentioned.

Nothing in this section contained shall take away from any person any right to take proceedings in respect of a claim for compensation for injury or death by accident, which he may have under any other Act other than this, if he prefer to proceed under such Act, but in such case he shall forfeit any right he may have to take proceedings under this section.

Notices of accidents and the provisions of coroners' inquests are as usual, but as distances are so great the Minister of Mines may authorize some person to act for the inspector. The writer remembers a case when a police-constable, who acted in this capacity, reported that the evidence "disclosed no blame to the Mines Department." Where practicable one-half the jurors are to be miners.

Section 59 deals with the resumption of land for mining purposes, and has an important bearing on the question of mineral rights. The provisions are as follows:—

- (1) All lands which, previous to the commencement of this Act, have been alienated or agreed to be alienated from the Crown, whether by way of absolute sale, or lease, or for any lesser interest, shall, with the consent of the owner or occupier thereof respectively; and
- (2) All lands which, after the commencement of this Act, may be so alienated, or agreed to be so alienated, from the Crown, but not expressly for coal-mining purpose, shall, without the consent of owners or occupiers thereof respectively; and
- (3) All native lands which have been alienated since the 30th day of August, 1888, or which hereafter may be alienated by the native owners thereof, to any person other than Her Majesty, except lands alienated expressly for mining or coal-mining purposes;

Shall be liable to be resumed by Her Majesty for coal-mining purposes on paying full compensation to the owner and occupier thereof for the value of the land and improvement so resumed.

Section 60 enables the Governor, on behalf of Her Majesty, to contract with the owner or lessee of any coal-mine either in native, private, or

Crown lands for the acquisition of such mine, "Provided that resumption and acquisition under this and the preceding section shall not be complete nor take effect until a resolution of the Legislative Council and the House of Representatives shall have been passed sanctioning the same. Any land so resumed or acquired may be worked by the Minister on behalf of Her Majesty, unless the Legislative Council and the House of Representatives shall by resolution otherwise determine."

Section 61 deals with the question of access to and wayleave through lands required, and is of great interest as bearing on the recommendations of the Royal Commission on Mining Royalties, whose report has recently been published, "Where, for the purpose of working any mine, it is required to carry any work on, or over, or under any private land, or to take any such land, or any part thereof, for mining works in connexion with such mine, the Governor, on the application and at the proper cost and charges of the owner of the said mine, may take such land, or any part thereof, under 'The Public Works Act, 1882,' as for a public work within the meaning of such Act. All provisions of the said Act shall apply accordingly for the purpose, but the effect of the Proclamation taking the land shall be to vest such land in the applicant instead of in Her Majesty, and all proceedings after the aforesaid Proclamation in respect of compensation and otherwise in respect of complying with the said Act shall be had against the applicant, who shall be deemed to be the respondent, and shall be liable in respect of such taking in the same manner and to the same extent as Her Majesty or the Minister for Public Works would be in respect of taking land for a Government work under the said Act."

Section 63. (Encroachment.) This section authorizes the Minister of Mines, on affidavit of any person claiming to be legally or equitably interested in any mine, to authorize the inspector, together with a "mining surveyor or experienced miner," to enter and survey, but the complainant is first to deposit a sum not exceeding £100 as security.

Section 65 deals with the flooding of adjoining mines, and enables any owner of a mine, who shall have left a barrier not less than 33 yards thick along his entire rise boundary, to recover from his neighbour, who may wilfully or negligently allow any water to overflow or percolate, a proportionate amount of the cost of pumping such water.

Section 68 requires the usual annual returns and also "any other information connected with the mine the Minister may from time to time require," and it authorizes the Minister to publish the result of such returns.

Section 69 is perhaps the most remarkable provision in the Act. It is a direct and heavy tax on a particular industry, and goes beyond the contract entered into between the Crown and the lessees, opening up a question of the gravest importance. As an attempt to relieve distress it is no doubt admirable, but, as was expressed by a leading mining man in New Zealand in a recent letter to the writer, "The principle of such a fund I do not object to, but I think it should be subscribed to by all parties concerned, starting with the lessor and ending with the men."

Its provisions are, shortly stated, as follows :—The owner of every coal-mine shall contribute one halfpenny per ton on the output of bituminous mines and one farthing per ton on any lignite sold during the preceding three months, and shall pay this into the Post Office Savings Bank to the credit of a fund to be called the "Sick and Accident Fund" in connexion with the miners' association of the district. In case of there being no miners' association the money is to be paid to the credit of a fund known as "The Coal Miners' Relief Fund." These moneys are to be operated upon "only by the persons appointed in that behalf by the miners' association of the district, in accordance with regulations to be from time to time made by the Governor," and where no such association exists the Minister of Mines and the Public Trustee are to act. The inspectors of mines are empowered to examine colliery accounts in order to see if the owners pay up regularly, and the penalty for not doing so (which goes to the credit of the fund) is two pounds for every pound or fraction of a pound not paid. There is one redeeming feature. In case of damages for injury, the amount to which a workman may be entitled from the accident fund is to be taken into account.

The final section in the Act provides that no contract for the supply of coal shall be binding in case of a strike.

6. ACCIDENTS.

As will be observed on reference to the following tables, coal-mining in New Zealand is subject to approximately the same proportion of accidents as occur in other countries, but owing to the limited number of men employed, the death-rate per thousand is very variable (Fig. 4, Plate III.). Many of the fatalities have occurred in small mines, where the owners have neither sufficient capital to provide proper appliances, nor in many cases the skill requisite for using them, were they at hand. Thus, in 1888, when there were four deaths, half this number took place in two mines, with a joint output of 30 tons.

Prior to 1879, statistics of mining accidents were not kept, and the following table therefore commences with the year 1880 :—

TABLE OF NUMBER OF DEATHS PER 1,000 PERSONS EMPLOYED IN
NEW ZEALAND COAL AND LIGNITE MINES.

Year.						Deaths per 1,000.
1880	...	...	...	...	..	2.50
1881	...	...	...	...	...	1.04
1882	...	...	...	...	...	1.91
1883	...	...	...	...	...	1.60
1884	...	...	...	...	...	2.34
1885	...	..	...	...	...	2.06
1886	...	...	...	...	...	0.00
1887	...	...	...	...	..	2.66
1888	...	...	...	...	...	2.36
1889	...	...	..	...	...	2.37
1890	...	...	...	...	...	4.33
1891	...	...	...	...	...	2.36

Average from 1879 inclusive (but not counting the Kaitangata explosion, which occurred prior to the enforcement of mining regulations) to the end of 1891 2.33

The following tables show the classification of accidents to the end of 1887 :—

TABLE OF PERCENTAGE OF TOTAL ACCIDENTS IN COAL-MINES, NEW ZEALAND,
1879 TO 1887 INCLUSIVE (NOT COUNTING THE KAITANGATA EXPLOSION).

Above—					Per Cent.
Falls of ground	...	...	...	...	1.23
Trucks	...	...	...	...	1.85
Powder	...	...	...	...	1.23
Miscellaneous	...	...	...	...	5.55
					9.86
Below—					
Falls of roof and sides	...	...	...	...	56.79
Trucks	...	...	...	...	14.81
Explosions of powder	...	...	...	...	4.32
„ „, fire-damp	...	...	...	...	4.94
Falls of timber	...	...	...	...	4.32
Miscellaneous	...	...	...	..	1.23
					86.41
Shafts—					
Falls down	...	...	...	...	0.62
In shafts	...	...	...	...	3.08
					3.70
					99.97

Of deaths alone the percentage for that period was as follows:—

Cause	Per Cent.
Explosion of gas	4·54
Falls below ground	68·18
Trucks below	9·08
Shafts	4·54
Falls of gravel above ground	9·08
Asphyxiated in shafts	4·54
	99·96

Thus 77·26 per cent. of the total fatalities is due to falls of ground.

The average number of men employed per life lost from 1879 to 1891 (inclusive) was 428·7, and the average tonnage raised per life lost was 149,524 tons.

7. TOTAL CONSUMPTION, OUTPUT, IMPORTS AND EXPORTS, ETC.

With only one very small exception, the total consumption of coal has gone on from year to year steadily increasing, as will be seen on reference to the following table and to Fig. 5, Plate III. :—

TABLE OF TOTAL CONSUMPTION OF COAL, NEW ZEALAND.

Year.	Quantity in Tons.	Increase.	Decrease.	Percentage Increase.	Percentage Decrease.
1877	294,980	—	—	—	—
1878	332,445	37,465	—	12·7	—
1879	382,099	49,654	—	14·09	—
1880	416,200	34,101	—	8·4	—
1881	460,598	44,398	—	10·6	—
1882	503,609	43,011	—	8·5	—
1883	538,132	34,523	—	6·41	—
1884	622,921	84,789	—	15·7	—
1885	638,894	15,973	—	2·56	—
1886	651,364	12,470	—	1·95	—
1887	652,899	1,535	—	0·20	—
1888	687,558	34,659	—	5·30	—
1889	675,218	—	12,340	—	1·79
1890	714,932	39,714	—	5·88	—
1891	765,019	50,087	—	6·54	—

The total output (Fig. 5, Plate III.) also shows a steady increase, except in the year 1889.

TABLE OF COAL OUTPUTS, NEW ZEALAND.

Year.	Quantity in Tons.	Increase.	Decrease.	Percentage Increase.	Percentage Decrease.
1877	138,984	—	—	—	—
1878	162,218	23,234	—	16·71	—
1879	231,218*	69,000	—	42·5	—
1880	299,923	68,705	—	29·7	—
1881	337,262	37,339	—	12·4	—
1882	378,272	41,010	—	10·8	—
1883	421,764	43,492	—	10·5	—
1884	480,831	59,067	—	14·0	—
1885	511,063	30,232	—	6·3	—
1886	534,353	23,290	—	4·5	—
1887	558,620	24,267	—	4·5	—
1888	613,895	55,275	—	9·9	—
1889	586,445	—	27,450	—	4·4
1890	637,397	50,952	—	8·7	—
1891	668,794	31,397	—	4·6	—

Imports.—The imports of coal into New Zealand will probably never entirely cease, for though the native coal is plentiful and good, New South Wales fuel will always command a market. This arises mainly from the fact that the latter colony is a very large customer for New Zealand farm produce, and the vessels, rather than come back empty, bring coal as a return freight. The following table and Fig. 6, Plate III., show the history and position of the trade :—

TABLE OF IMPORTS OF COAL INTO NEW ZEALAND.

Year.	Quantity in Tons.	Increase.	Decrease.	Percentage Increase.	Percentage Decrease.
1877	155,996	—	—	—	—
1878	174,148	18,152	—	11·6	—
1879	158,076	—	16,072	—	9·2
1880	123,298	—	34,778	—	22·0
1881	129,962	6,664	—	5·12	—
1882	129,582	—	380	—	0·2
1883	123,540	—	6,042	—	4·66
1884	148,444	24,904	—	20·1	—
1885	130,202	—	18,242	—	12·28
1886	119,873	—	10,329	—	7·93
1887	107,230	—	12,643	—	10·55
1888	101,341	—	5,889	—	5·49
1889	128,063	26,722	—	26·37	—
1890	110,939	—	17,124	—	13·37
1891	125,318	14,379†	—	12·96	—

* The abnormal increase of the year 1879 over that preceding is due to the fact that a large number of coal-mines which had not previously received official notice were at that time, owing to the enforcement of legislation relating to mining, added to the list. By this means the number on the record was raised from 30 to 90.

† This increase was caused to some extent by the strikes in New Zealand, which caused foreign coal to be poured in. For instance, one line of steamers imported 4,621 tons from Europe.

RETURN SHOWING THE QUANTITY AND VALUE OF COAL IMPORTED INTO
NEW ZEALAND DURING THE YEAR ENDING DECEMBER 31st, 1891.

Countries whence Imported.	Quantity in Tons.	Value. £.
United Kingdom	962	1,030
Victoria	1,246	1,304
New South Wales	120,775	116,320
Queensland	2,335	1,768
Total	125,318	£120,422

Exports.—In considering the exports of coal from the colony, it is necessary to distinguish between that which is actually exported to a foreign country there to be consumed, and that which is put on board the direct steamers to be burned on the voyage. In Table A, this quantity is counted, where obtainable, as consumed within the colony; and in table B, it is treated as export. (See Fig. 6, Plate III.)

TABLE A.—EXPORTS OF COAL FROM NEW ZEALAND (COUNTING DIRECT
STEAMER CONSUMPTION AS CONSUMED IN THE COLONY).

Year.	Quantity in Tons.	Increase.	Decrease.	Percentage Increase.	Percentage Decrease.
1878	3,921	—	—	—	—
1879	7,195	3,274	—	83·5	—
1880	7,021	—	174	—	2·4
1881	6,626	—	395	—	5·6
1882	4,245	—	2,381	—	35·9
1883	7,172	2,927	—	68·9	—
1884	6,354	—	818	—	11·4
1885	2,371	—	3,983	—	62·6
1886	*	—	—	—	—
1887	12,951	—	—	—	—
1888	23,783	10,832	—	83·6	—
1889	39,290	15,507	—	65·2	—
1890	33,404	5,886	—	--	14·9
1891	29,093	4,311	—	—	12·9

* The figures for 1886 are not obtainable. This has destroyed the continuity of the table.

TABLE B.—EXPORTS OF COAL FROM NEW ZEALAND FROM 1884, WITH THE DIRECT STEAMER CONSUMPTION TREATED AS EXPORT.

Year.	Quantity in Tons.	Increase.	Decrease.	Percentage Increase.	Percentage Decrease.
1884	6,354	—	—	—	—
1885	45,493	39,139	—	—	—
1886	47,037	1,544	—	3·39	—
1887	44,129	—	2,908	—	6·18
1888	68,087	23,958	—	54·29	—
1889	82,670	14,583	—	21·4	—
1890	76,388	—	6,282	—	7·6
1891	99,464	23,076	—	30·2	—

The following table gives details of the countries to which the above amounts for 1891 were sent :—

RETURN SHOWING THE QUANTITY AND VALUE OF COAL EXPORTS FROM NEW ZEALAND DURING THE YEAR ENDING DECEMBER 31ST, 1891.

Countries to which Exported.	Quantity in Tons.	Value. £.
United Kingdom*	70,371	78,050
Victoria	157	102
New South Wales	8,952	8,269
Queensland	70	81
South Australia	7,701	3,360
Western Australia	89	45
Tasmania	19	22
Norfolk Island	74	80
Fiji Islands	3,421	2,602
U.S. America (East Coast)	2	2
Chili	407	509
South Sea Islands	8,201	7,536
Total	99,464	£100,658

Of this, 2,968 tons, valued at £3,348, was foreign coal, the rest was New Zealand produce.

TABLE OF PROPORTION OF IMPORTED COAL TO TOTAL CONSUMPTION, NEW ZEALAND. (See Fig. 7, Plate III.)

	Percentage of Imported Coal to Total Consumption.		Percentage of Imported Coal to Total Consumption.
1878	52·3	1885	20·3
1879	41·4	1886	18·4
1880	29·6	1887	16·4
1881	28·21	1888	14·7
1882	25·7	1889	18·9
1883	22·9	1890	15·5
1884	23·8	1891	16·37

* For direct steamers.

The following tables, and Fig. 5, Plate III., show the output of coal and percentage increase or decrease *per annum* for each island :—

OUTPUT OF COAL, NORTH ISLAND, NEW ZEALAND.

Year.	Output in Tons.	Increase.	Decrease.	Percentage Increase.	Percentage Decrease.
1878	58,900	—	—	—	—
1879	75,070	16,170	—	27·4	—
1880	96,345	21,275	—	28·3	—
1881	90,734	—	5,611	—	6·18
1882	96,151	5,417	—	5·9	—
1883	92,762	—	3,389	—	3·5
1884	103,903	11,241	—	10·81	—
1885	111,734	7,831	—	7·53	—
1886	104,794	—	6,940	—	6·2
1887	98,710	—	6,084	—	5·8
1888	108,538	9,828	—	9·9	—
1889	94,255	—	14,283	—	13·16
1890	115,917	21,662	—	22·9	—
1891	104,064	—	11,853	—	10·2

OUTPUT OF COAL, SOUTH ISLAND, NEW ZEALAND.

Year.	Output in Tons.	Increase.	Decrease.	Percentage Increase.	Percentage Decrease.
1878	103,318	—	—	—	—
1879	156,148	52,830	—	51·1	—
1880	203,248	47,100	—	30·1	—
1881	246,529	43,281	—	21·2	—
1882	282,121	35,592	—	14·4	—
1883	329,002	46,881	—	13·07	—
1884	376,828	48,826	—	14·8	—
1885	399,329	22,452	—	5·9	—
1886	429,559	30,230	—	7·57	—
1887	459,910	30,351	—	7·06	—
1888	505,357	45,447	—	9·87	—
1889	492,190	—	13,167	—	2·6
1890	521,480	29,290	—	5·9	—
1891	564,730	43,250	—	8·29	—

MINING IN NEW ZEALAND.

he following table indicates more clearly how the ratio of increase South Island exceeds that in the North :—

TABLE SHOWING PERCENTAGE OF TOTAL OUTPUT OF COAL CONTRIBUTED BY THE NORTH ISLAND, NEW ZEALAND.

				Percentage Contributed by North Island.					Percentage Contributed North Isd
1878	...	...	...	36·3	1885	...	...	...	21·8
1879	...	...	...	32·46	1886	...	...	...	21·8
1880	...	...	...	23·1	1887	...	...	...	17·6
1881	...	...	...	26·9	1888	...	...	...	17·6
1882	...	...	...	25·4	1889	...	...	...	16·0
1883	...	...	...	17·2	1890	...	...	...	18·1
1884	...	...	...	21·6	1891	...	...	...	15·5

The following table gives some details of the outputs of the various districts for the years 1890 and 1891, and the approximate total output since records have been kept :—

TABLE SHOWING THE OUTPUT OF COAL FROM THE VARIOUS MINING DISTRICTS AND THE INCREASE OR DECREASE FOR THE YEARS 1890 AND 1891, TOGETHER WITH THE TOTAL APPROXIMATE QUANTITY OF COALS PRODUCED.

District.	Output.		Increase.	Decrease.	Approximate Total Output to Dec. 31/ 1891.
	1890.	1891.			
Kawakawa ...	30,367	28,254	—	2,113	769,5
Whangarei ...	19,633	16,228	—	3,405	265,
Waikato ...	64,729	55,869	—	8,860	596
Mokau ...	1,188	3,713	2,525	—	4
Pelorus (Picton) ...	—	—	—	—	
West Wanganui and Collingwood	4,092	3,328	—	764	
Westport ...	170,406	206,184	35,778	—	1,1
Reefton ...	6,010	4,556	—	1,454	
Greymouth ...	118,847	145,351	26,504	—	1,
Malvern ...	15,083	14,775	—	308	
Timaru ...	1,430	1,488	58	—	
Otago ...	176,428	164,870	—	11,558	
Southland ...	29,184	24,178	—	5,006	
Totals ...	637,397	668,794	64,865	33,468	
			Net increase, 31,397		

The following table classifies the different varieties of coal :—

TABLE SHOWING THE DIFFERENT CLASSES OF COAL FROM THE MINES IN NEW ZEALAND.

Name of Coal.	Output of Coal.		Increase.	Decrease.	Approximate Total Output to Dec. 31st, 1891.
	1890.	1891.			
Bituminous ...	323,712	387,839	64,127	—	3,531,749
Pitch ...	124,593	96,979	—	27,614	1,112,965
Brown ...	171,725	161,904	—	9,821	2,275,364
Lignite ...	17,367	22,072	4,705	—	211,908
Totals ...	637,397	668,794	68,832	37,435	7,131,986
			Net increase, 31,397		

The following table gives an indication of the relative number of men employed and average output per man in the different sized mines. It supports what the writer has mentioned relative to the inconstant employment and consequent small output of the very small pits :—

TABLE SHOWING THE NUMBER OF COAL-MINES IN OPERATION, THE NUMBER OF MEN EMPLOYED, AND THE OUTPUT OF COAL PER MAN.

Number of Mines Working.	Number of Miners Employed in each Mine.	Total Number of Men Employed.	Output of Coal During 1891.	Average Output per Man.
96	1 to 4 men in each	196	Tons. 49,416	Tons. 252
15	5 to 10 „ „	107	30,587	285
6	11 to 20 „ „	95	22,141	233
16	21 men and upwards	1,295	566,650	437
133	Totals ...	1,693	668,794	395

The discrepancy between the number of mines given above and that given in the table on page 58 has been already explained.

8. QUANTITY OF EXISTING COAL.

The difficulty of determining the total quantity of coal contained in any country has been well exemplified in the case of Great Britain, and it is obviously impossible in a place like New Zealand to make even an approximate estimate. Sir James Hector, however, whose knowledge of the coal-fields is unequalled, has published his opinion on this point,* as follows :—

* *Report of Westland Coal-fields Committee, 1889, page 104.*

ROUGH ESTIMATE OF THE PROBABLE AREA AND QUANTITIES CONTAINED
IN THE NEW ZEALAND COAL-FIELDS.

No.	Name.	Acreege of Coal-measures.	Tons.
1	Kawakawa	19,200 ...	11,360,000
2	Waikato	64,000 ...	51,200,000
3	Mokau	16,800 ...	32,720,000
4	Collingwood	46,000 ...	15,000,000
5	Karamea	13,400 ..	5,360,000
6	Wangapeka	12,800 ...	5,520,000
7	Matiri	10,800 ...	4,700,000
8	Buller	115,200 ...	138,240,000
9	Reefton	12,800 ...	5,120,000
10	Grey	44,800 ...	53,760,000
11	Clarence	6,400 ...	2,560,000
12	Malvern	9,600 ...	7,680,000
13	Somers	1,920 ...	768,000
14	Kakahu	3,200 ...	1,280,000
15	Shag Point	19,200 ...	8,600,000
16	Green Island	9,600 ...	11,280,000
17	Clutha	32,000 ...	51,000,000
18	Winton	16,000 ...	12,800,000
19	Nightcaps	32,000 ...	25,000,000
Total			448,948,000

9. WAGES, STRIKES, BENEFIT CLUBS, CONDITION OF THE
MINERS, ETC.

Wages have already been referred to, and vary from about 12s. per day on the West Coast, where living is expensive, to 7s. below ground and 6s. above on the eastern side of the South Island.

The following are some prices for contract work in 1890:—Stone-drift, 6 feet by 6 feet, mostly conglomerate, dipping 1 in 7, haulage supplied by owners, otherwise the price includes labour and explosives, £3 10s. 6d. per yard; drifting, 6 feet by 6 feet in coal shales, including timbering, £1 19s. per yard; coal-heading, 4s. to 7s. 6d. per yard, and 4s. per ton for coal, and 1s. for slack; coal-getting (in Canterbury), 3s. per ton for all-over 1 inch riddle, regular work.

It is always difficult to calculate the earnings of miners, especially when the number employed is somewhat variable, as is the case in New Zealand. The method employed in the last Mines Department report of the colony is as follows:—The total quantity of coal raised in tons is multiplied by six shillings, which is supposed to represent the average cost in wages of getting a ton of coal. This gives £200,638, and as 1,693 men were employed (1,277 below and 416 above ground) the average earnings of each is £118 10s. 2d. per annum, a very large sum, but one which, when the cost of living is taken into account, must be heavily discounted before being compared with the remuneration in Great Britain.

Strikes unfortunately are not unheard of, and have been carried to a pitch unknown in England. An institution known as the “complete

boycott" has been established, which requires some explanation. A and B (say) own a coal mine, and also a woollen factory. A is also a partner in a merchant's business. The men at the colliery strike or are locked out. The labour leaders give notice that A and B are to be boycotted. No member of any carriers' union is to touch a bale bound for the factory or a package from the store. No railway or steamship is to carry a single article bearing the name of either the woollen company or the merchant's business, under penalty of an immediate cessation of work on the part of all hands. This desperate style of warfare which involved workmen who had nothing whatever to do with the matter under dispute, and simply amounted to a display of strength, wrought its own cure, and ended in a bitter disappointment to the men—ruin in fact to many—enormous loss of trade to the Colony, and great privation for women and children. The capitalists at once rose to the occasion and worked their undertakings with "free labour."

On the West Coast of the South Island in 1891, it became necessary to employ non-union men, working under police protection, and housed and fed on the works. In order to ensure their safe transit from the railway train to the mine, special constables were enrolled and the somewhat unusual course was adopted of swearing in, as temporary guardians of the peace, about 100 of the most prominent union men, who were accordingly drawn up in line to preserve order, while those who were coming to take their work marched between.

Benefit societies and sick-and-accident clubs were common at all the larger works, but the direct taxation of the owners to provide for requirements of this nature will presumably have checked, if it has not killed, these organizations.

As regards wages, money is tolerably plentiful, and men can, if they like, save. The West Coast is wet and rough, and living is expensive; houses too, as in all new countries, are at a premium, but land can easily be obtained, and the style of dwelling considered in the colonies sufficient for a small family does not take long to run up, and is easily sold. In the agricultural districts, the colliers frequently have a piece of ground and often keep a horse, while shooting and fishing are in places to be had at very small cost. Free education for children is usually at hand, but if not, and there should be a railway, they travel free to the nearest station where there is a school. Libraries and reading rooms, schools of mines, and other means of passing the time profitably are plentiful, and there are so many local bodies that a considerable amount of attention is taken up with what may be called "parish politics."

While colliery working in some parts of New Zealand is an operation requiring great perseverance and large capital, there are many places among the brown coals and lignites where a pick and shovel, with a few days' or weeks' labour, will suffice to open what is undoubtedly a coal-mine. Nearly all over the interior of Otago are patches of lignite, sometimes hidden by the surface-soil and vegetation, and sometimes exposed in the beds of watercourses. When these seams penetrate deep into the soil an adit is required instead of a simple opencast working; and then, in addition to the actual tools required for breaking ground, comes the necessity for the purchase of a truck, a little sawn timber for rails, and some prop-wood, which is very dear in places, costing as much as 1s. per foot for a 5 or 6 feet prop. Even in this case the requisite outlay is not large, and for men who have a love of independence, an undertaking of this nature, even though it may not hold out any prospect of riches, offers the inducement of freedom with frequently a comfortable living. Many proprietors of these small concerns get the coal, tram it out, and cart it to the consumer. This system dispenses entirely with the middleman, and brings to the fore a class of self-reliant hard-working men who occasionally are fortunate enough to escape over-competition, and by dint of perseverance and labour attain a competency.

As years go on the opportunities of working without capital will grow less plentiful, and as railways increase the trade will fall into the hands of the larger companies.

10. CONCLUSION.

The writer trusts that in the foregoing pages he has given an impartial and fairly accurate account of coal-mining in New Zealand. The figures dealt with are in many cases small, as compared with the armies of workmen and stupendous output of the mother country, but the colony is equipped with stores of mineral fuel which will some day materially help it to assume its proper position among the nations which are springing up under the old flag. As an integral part of this great empire its future prospects cannot be without interest to those who desire to see English-speaking miners and mining engineers supreme in all quarters of the globe.

PART IV. KAURI-GUM.

As a fossil resin dug from the earth kauri-gum has undoubtedly a place among the mineral productions of the colony, and, as will be seen from the following table, it forms a by no means unimportant article of export. It is the fossil turpentine of the Kauri (*Damara australis*), which is still found growing in the northern portion of the colony, and

occurs as far south as Taranaki. Though used principally in the manufacture of varnish, it is stated to be employed as a substitute for amber, which it very much resembles. As the method of mining for kauri-gum is very simple—nothing more is required than a spear with which to find it, a spade to dig it out, and a sack to carry it away in—it is a frequent refuge for people who have not sufficient capital to embark in any other industry, who are not over-fond of work, but like a free and open-air life, and who desire to obtain something which is readily convertible into cash. As the climate of the region where it occurs is very mild, and the country comparatively open, but little hardship need be encountered by the “gum-digger.”

TABLE, SHOWING EXPORT OF KAURI-GUM FOR THE YEARS 1890 AND 1891, AND ALSO THE TOTAL AMOUNT EXPORTED FROM JANUARY 21ST, 1853, TO DECEMBER 31ST, 1891.

		Tons.		Value.
1890		7,438	...	£378,563
1891		8,388	...	£437,056
From January, 1853, to December 31st, 1891 ...		143,018½	...	£5,831,743

Apropos of kauri-gum, the mineral ambrite may be mentioned, though it has not as yet been commercially utilized. It occurs plentifully in many places, and has been described by Dr. von Hochstetter,* as follows:—“Fossil resin embedded in the coal, sometimes in pieces from the size of a fist to that of a man’s head, but usually only in smaller groups. It is transparent, very brittle, and has a conchoidal and quite glossy fracture. Colour changes from a bright yellow to dark brown; is easily ignited, much more so than kauri-gum, burns with a steady fast-sooting flame, and develops a bituminous rather than an aromatic smell. Mr. Richard Maly found as a mean of three chemical analyses of this fossil resin:—

			Computed.
Carbon	76.53	...	76.65
Hydrogen	10.58	...	10.38
Oxygen	—	...	12.78
Ash	0.19	...	0.19
			100.00

yielding the formula $C^{82} H^{26} O^4$. It shows great indifference to solvents; by friction it becomes electric; hardness, 2; specific gravity, 1.034 at 12 degrees Reamur. It is sufficiently characterized to deserve a special name, but it comes so near to real amber in composition that it deserves the name of ambrite.”

The writer has now to conclude with a word of explanation what has been to him a congenial labour. The colony of New Zealand is an extensive and varied tract of country, embracing every variety of topography,

* *New Zealand*, 1863, English edition, page 79.

Mr. T. E. FORSTER said he had had the pleasure of seeing one of the New Zealand coal-mines by the assistance of Mr. Binns, who was kind enough when he Mr. Forster was in London to show him the Kaitangata colliery mentioned in the paper. He was interested by the ingenious way in which the manager had contrived to overcome many of the difficulties. He would like to ask Mr. Binns whether all the coal on the West Coast was capable of being made into coke. He gathered from the paper that the proposal to supply New Zealand coke to Broken Hill had not been a success: if the coal was so free from ash, as stated, it seemed strange that it had not been able to compete with English coke. Mr. Binns showed how the Colonial Government took over and resumed land for the purpose of colliery-railways or mining-works. The law was practically the same in Australia so far as railways were concerned, but it must be remembered that the physical characteristics of the country are very different from those existing at home. Everything which gave employment in Australia was considered as a matter of public utility, but that standard of excellence had not been yet attained in this country.

Prof. HULL said Mr. Binns' paper seemed to contain a most valuable synopsis of the coal-fields of New Zealand, in which the writer had gathered into a very small space a large amount of useful information. It was a remarkable fact, notwithstanding the proximity of the two countries, that the coal-fields of New Zealand should be geologically of much more recent date than those of Australia. The great coal-bearing tracts of Australia were either of the same Carboniferous age as the coal-fields of the British islands, or very nearly verging thereon, but those in New Zealand were very much more recent, being of the period on the borderland between the Secondary and Tertiary rocks, consequently they could not expect the coals to be so highly mineralized as they were in Australia, in the British Isles, or in America. He would not have considered the Westport coal to be a good steam coal, and it was remarkable that it should have given such excellent results as were indicated on page 45. He was going to venture on a generalization which he hoped might not be considered out of place. It was to the effect that wherever the Anglo-Saxon race had colonized, whether in America, in Australia, or in New Zealand, that race always seemed to find at hand the materials necessary for the development of its industries to the highest degree. These coal-fields in New Zealand might have lain for incalculable ages useless in the hands of the Maoris, for many years would have passed before they would have developed a steam-engine or sunk a shaft.

To illustrate Mr G. J. Birns' Paper on "Mining in New Zealand"

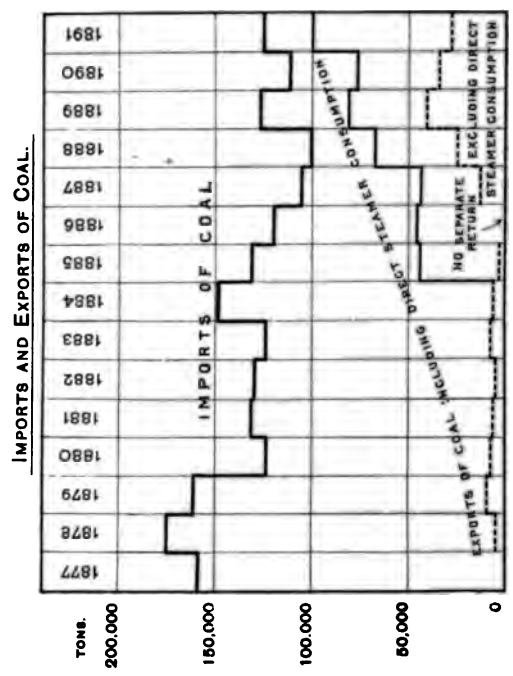


FIG. 6.

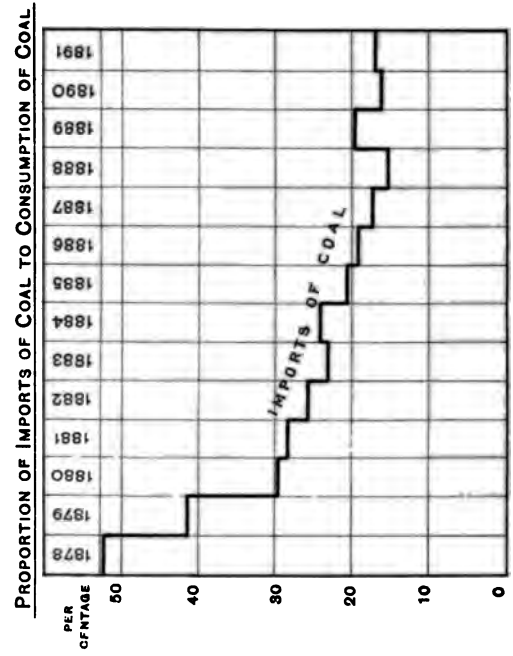


FIG. 7.

Am. & Eng. Soc. of Civil Engineers

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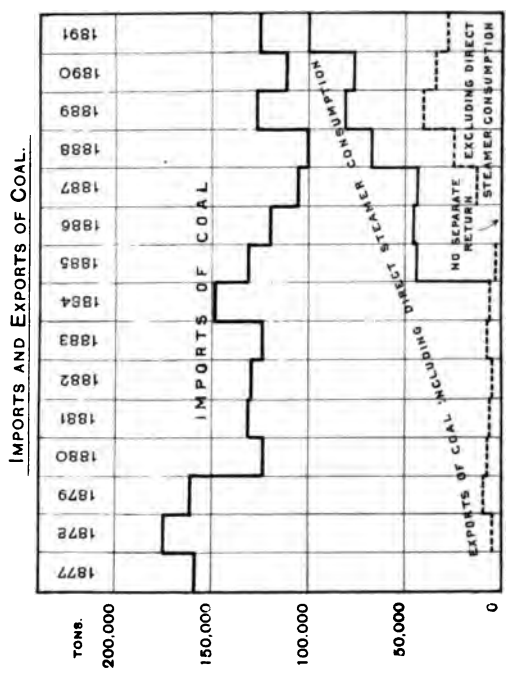


FIG. 6.

And "Read Sons & Co. Ld. Newcastle"

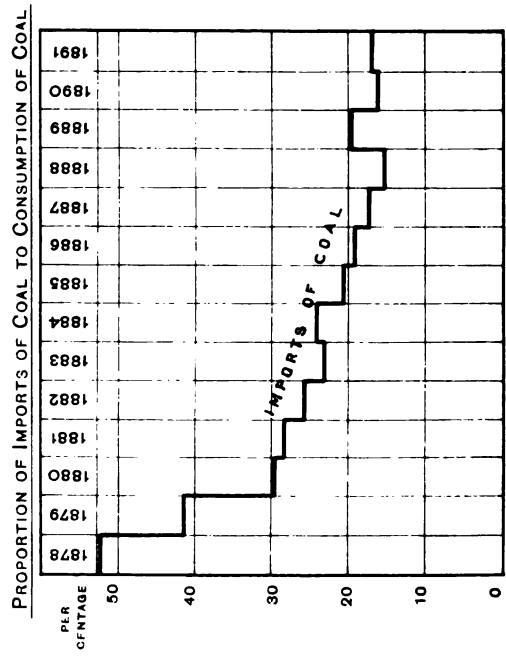


FIG. 7

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The PRESIDENT moved a vote of thanks to Mr. Binns for his excellent paper, which was an exceedingly valuable contribution to the *Transactions*, and, he thought, would form a useful work of reference in connexion with the working of mines in New Zealand.

Mr. T. E. FORSTER seconded the motion, which was cordially adopted.

Mr. BINNS said he was exceedingly obliged to the President for proposing, and to the members for carrying, the vote of thanks. He thought it a sufficient privilege to be allowed to publish what little he knew in the *Transactions* of the Institution, without being specially thanked for it. The West Coast coal made very good coke, but the freedom from ash was not always the same as in the Westport. Greymouth coal contained from 3·81 to 6·45 per cent. of ash, and that seam was made into coke to a large extent, but it did not appear, from the recent report of the Minister of Mines, to have been a success.

Mr. G. E. COLLINS read the following paper by Mr. Arthur L. Collins on "Fire-setting: The Art of Mining by Fire":—

FIRE-SETTING: THE ART OF MINING BY FIRE.

 By ARTHUR L. COLLINS.

In olden times, before the invention or common use of explosives, the best method available for mining through the hardest kind of rock, such as resisted the use of hammer and wedge, was by means of fire. It is true that other methods were probably known; thus there is reason to believe that the Egyptians possessed tools capable of boring holes into the hardest rocks,* and commonly split off huge blocks by driving wedges into a series of such holes, just as granite is often split by plug-and-feather at the present day. It is also possible that the northern nations were able to break rocks by allowing water to freeze in similar tightly-plugged holes, but each of these processes would be more applicable to quarrying than to real mining underground. The ancients generally seem to have avoided working in the hardest rocks: thus the extensive rock-cut temples and tombs of Syria, Egypt, and India are mostly excavated in soft sandstone or limestone—they seem indeed often to be merely natural caverns, enlarged and chiselled by man. Where masses of exceptionally hard rock were met with, work was either suspended or the ground loosened by previous heating.

Nothing is more natural than that the effect of fire on rocks should have been known at a very early period; no one who has lighted a fire on rock can help noticing the rending effect of the heat. The same thing would be seen after any natural forest fire; several examples on a very extensive scale have recently come under the writer's notice in Australia, where bush fires of great extent are frequent, and all the rock cropping out at the surface is seen to be cracked and split over great areas. Similar forest fires were supposed to have led to the discovery, by some Phœnician sailors, of silver in the Pyrenees, according to Diodorus.†

The fire-setting process seems to have been known to the Jews‡ and to the Greeks; while Diodorus describes its use in the gold-mines of Arabia and Ethiopia, where gold seems to have occurred in white shining veins of quartz, glistening with all sorts of other bright metals. He says: "The earth which is hardest and full of gold they soften by putting fire

* The coffer in the Great Pyramid shows marks of jewel-tipped boring-tools, according to Mr. Flinders Petrie.

† Diodorus Siculus, book v., chap. ii., page 320 of Booth's translation. See also Lucretius, Creech's translation, vol. ii., page 572.

‡ Jeremiah, chap. xxiii., verse 29.

under it, and then work it out with their hands.”* In describing the gold mines in Spain, Pliny says: “In mining either by shaft or by gallery barriers of silex are met with, which have to be driven asunder by the aid of fire and vinegar . . . which method fills the galleries with suffocating vapours and smoke.”† According to Pliny, vinegar poured upon the heated rocks in considerable quantities has the effect of splitting them, when the action of fire alone has been unable to produce any effect;‡ and according to Livy, Hannibal appears to have used a similar method for removing rocks during his passage of the Alps. This use of vinegar does not seem to have been tried in later times, although water has often been used to suddenly cool the heated rock.

For many centuries after the breaking up of the Roman power, mining seems to have fallen to a very low ebb throughout Europe; but already in the eleventh century it appears that mines of argentiferous galena were re-opened in Sardinia by the Pisans, and shafts sunk to a depth of 600 feet by fire-setting;§ and as early as 1359 it was used in Germany on the Rammelsberg;|| indeed, it seems to have been the usual mining process for very hard rock during the Middle Ages. Agricola, writing in the sixteenth century, gives a complete explanation of the method then in use, with rude drawings illustrating the process.¶ According to Serlo, its use was retained at Mansfeld up to 1721, and at the Rammelsberg mines up to 1878, about 250 years after the introduction of powder for blasting purposes; for, as will presently be shown, it was not because of the superior efficiency of powder that the fire-setting method was discontinued, but rather because of the increasing cost of firewood and labour, and a growing regard for the health of the workpeople.

It does not appear that the process was ever much used in Cornwall; it is not mentioned by either Carew or Pryce, although T. Tonkin, who added notes to an edition of the former writer in 1733, says: “When they meet with rocks and very hard ground, . . . with such as require not only three weeks but three months to hew so many feet through the same, they formerly burnt furze and faggots, etc., to break the rocks; but that proving insufficient, and very often fatal to the workmen by the sudden change of wind, which drove down the smoke upon them and suffocated them, they of late had recourse to gunpowder.”** All the earliest workings in Cornwall seem to have been stream works, or open cuttings on the

* Diodorus Siculus, book iii., chap. i., page 158 of Booth's translation. † Pliny, *Natural History*, book xxiii., chap. xxi. of Bostock and Riley's translation. ‡ *Ibid.*, book xxiii., chap. xxvii. § Karsten, *System der Metallurgie*, Berlin, 1831. || Serlo, *Leitfaden zur Bergbaukunde*, 1884, page 326. ¶ Georgii Agricola, *De Re Metallica*, Basileæ, 1567, page 80; and the same writer's *Bergwerck Buch*, 1621. ** R. Hunt, *British Mining*, page 67.

backs of the lodes, which are generally fairly soft in their richest parts; so that fire-setting would have been unnecessary. In later times, when deep mining became more frequent, the increasing scarcity of suitable timber would have prevented any wide use of the method; for the forests which had originally covered the country were almost entirely destroyed to supply the various tin-smelting works, as lamented by Pryce, in 1778.*

There is however much evidence of fire-setting having been largely used in other parts of the British Isles. Thus Hunt quotes from Mr. Weston, of Machynlleth (1858), who had opened up an ancient shaft about 50 feet deep, where an iron pick and other tools, supposed to be Roman, were found, "We find at the bottom of our work much burnt wood, and it is evident they had recourse to fire as an agent—whether to soften the rock, or to heat it for the purpose of throwing water on it to crack it, I am not skilled to say, but that fire was used is certain."† Again, on page 166, Hunt quotes a paper by Mr. John Taylor, in the *Transactions of the Geological Society of Dublin*, from which it appears that when the Milltown lead mine in Clare was re-opened, they found, besides wooden and iron tools, "the remains of fires which had evidently been made use of to crack and loosen the masses of calcareous spar and carbonate of lime, in which the ore of this mine is chiefly embedded." The Cumberland miners, in 1282, claimed a right to take any wood near their mines, and to use it for burning, dispersing, and smelting.‡ An ancient charter illustrating the mode of working in the Mendips (about 1480) gives a rude attempt at representing fire-setting, with "This is a fire" written under it; and clause 10 of the charter itself ("The Lawes of ye Myne deeps") provides for the burial of the bodies of men killed underground by accident, or by stifling with fire.§ The old laws regulating mining in Derbyshire, dating from 1601, provide that fires may only be set in a rake or vein after working hours (4 p.m.), and that due notice must be given to neighbours; also that when two veins are divided by a thin parting, which may be mined by firing (*i.e.*, fire-setting) at one side only, they shall be workable by one miner;|| thus clearly showing that the process was in common use. The mode of working the narrow Derbyshire veins is clearly explained in Farey's *Derbyshire* (1811). "Previous to the use of gunpowder in mining, fires of dry wood were made against the forefield of the vein, which, owing to the heat, loosened and slapped off By means of these fires it is surprising to see what narrow veins, mere 'scrins,' the old men contrived to work for great distances into the rock, using

* W. Pryce, *Mineralogia Cornubiensis*, book v., chap. iii., page 281. † R. Hunt, *British Mining*, page 40. ‡ *Ibid.*, page 148. § *Ibid.*, pages 134 and 137. || J. Mander, *Derbyshire Miner's Glossary*, 1824, pages 100 and 129.

long-handled rakes or hoes to draw out the loosened ore and spar.”* Altogether, Hunt seems himself to supply ample evidence to refute his own conclusion (page 563) that “it is only under the most peculiar cases that it (*i.e.*, the application of fire) is ever used.”

Fire-setting has also been employed by the Indians of New Mexico from time immemorial in the mining of turquoises at Los Cerillos,† and other places in America; and according to Prof. H. S. Munroe, it is still used very largely for driving long tunnels in Japan.‡

Many of the old iron-mines of Sweden and Norway were once largely worked by the fire-setting process; the rocks being generally extremely hard and fairly dry, and firewood being very abundant. These mines can generally be easily identified, by the absence of boreholes, the frequency of rounded or conchoidal cavities in the roof where the flame has played fiercely upon it; and, more characteristically still, by the waste-heaps or “burrows” being composed of thin flakes of split-off rock, sometimes as much as a square foot in area, with a thickness of less than an inch. During the past summer the writer had occasion to visit some of the old iron-mines near Arendal, in Norway, where the three processes of fire-setting, blasting with powder in large holes, and with dynamite in small holes, have been successively in use; and the difference in general appearance of the levels and waste-heaps would be obvious to the most casual observer.

The use of fire-setting has not been by any means confined to the sinking of shafts and the drivage of levels: it is even better adapted for working stopes and rises, from the better upward action of the flames, and the absence of water. Cancrinus, writing in 1767, says that at Rammelsberg, when the walls of the vein were strong, most of the ore was stoped by fire-setting, and gives an illustration showing how the “deads” were built up, and wood placed on the top, just under the ground to be stoped, so that the fire could act with the best effect;§ and Callon reproduces an old figure from Delius, showing that lengths of 40 yards or more of stope were lit up and attacked by fire at one operation.|| When working on this scale, the wood would naturally be fired at the end of the week, so as to be burnt out when the miners were ready to begin the next week’s work. It is possible that the origin of the modern method of “overhand stoping”—so early developed in Germany—is

* R. Hunt, *British Mining*, page 144. † *Report of the United States Census Office, Journ. Soc. Arts*, vol. xxxix., page 821. ‡ H. S. Drinker, *Blasting, etc.*, New York, 1883. § Franz Ludwig Cancrinus, *Beschreibung der Bergwerke*, Frankfurt, 1767, page 95, *et seq.* || Callon, *Mining*, translated by Messrs. Foster and Galloway, vol. i., page 176, also figs. 121 and 122.

traceable to this extensive use of fire-setting in overhead stopes, by the old German miners.

The great trouble with fire-setting seems always to have been the heat and smoke produced—the latter being often strongly sulphurous, where the ore contained pyrites or other sulphides. Nearly all the old writers mention this trouble: thus Löhneyss says that “the miners suffered terribly from the fumes; and that at the St. Georg mines the heat was so great that melted silver is said to have flowed from the working-faces,”* and other instances have already been mentioned. It is easy to see that this would have been a great obstacle, when the means of artificial ventilation were so imperfectly understood; but it applies far less at the present day. Indeed, by a proper system of ventilation with upcast and downcast shafts, it need be no more objectionable than the ventilating-furnaces still used in some collieries; and at Kongsberg silver-mine in Norway, the system is still used occasionally for driving levels, mainly on account of the great improvement in ventilation which it causes throughout the mine.

The writer has recently had an opportunity of seeing the process at work in the Kongsberg mine, and as it is perhaps the only place of importance in Europe where it still survives, a few details of the mode of working may be of interest.

The process is now confined to the occasional drive of levels in hard siliceous gneiss—it having been found that the mica-schist and other micaceous rocks, which also occur at Kongsberg, are far less favourable for fire-setting. A short piece of level is driven at first in the ordinary manner, to get room to start the process; and wood—mainly logs of white fir and red pine, dry and split—is closely piled up so that the fire plays against the “face;” waste wood or old timbers from the mine being often piled against the freer-burning fir, to concentrate the heat. When the pile is lit, smoke fills the level, and the men leave it, but in two or three hours it is generally burnt out, and as soon as the men can come in, the broken stone which has split off is cleared away, and all that is sufficiently loose is broken down. The fire sets stronger on the roof and sides than on the sole, so that the levels have a constant tendency to slope upwards. This can partly be prevented by better arrangement of the fuel, putting long pieces at the bottom and covering the upper part; but sometimes the sole has to be blasted. The ordinary speed of driving is from 5 feet to 20 feet per month.

Prof. Helland† states that fire-setting kept its place as the common

* Löhneyss, *Bericht vom Bergwerck* (1617).

† A. Helland, *Grubedrift*, Kristiania, vol i., page 86.

method at Kongsberg so long as double-handed boring, iron borers, and powder were used ; but that on the introduction of single-handed boring, steel borers, and dynamite or other high explosives, the use of the old method rapidly died out. He gives the following figures, showing the relative cost of driving a level 6 feet 6 inches high by 5 feet wide, for each fathom of length :—

DURING 1860-1864, WITH POWDER.

	Day's work.	Materials.			Smithing.		Wages.			Total.			Wages per Man per Shift.	
		£	s.	d.	s.	d.	£	s.	d.	£	s.	d.	s.	d.
Hand-boring	47½	1	8	6	10	2	7	12	5	9	11	1	3	0
Fire-setting	34½	4	3	4	—	—	3	7	0	7	10	4	1	10½

DURING 1881-1885, WITH DYNAMITE.

Hand-boring	16½	2	0	8	6	1	3	9	1	5	15	10	4	4½
Fire-setting	38½	3	17	2½	—	—	4	5	4	8	2	6½	2	4

It will be seen that in 1864, fire-setting was both cheaper and quicker than the old method of blasting with powder in large holes ; but on the introduction of dynamite and small holes, things were entirely reversed ; not only did the new method effect a great saving in time and cost, but fire-setting became actually dearer than before, owing to the increasing wages. It should be added that at Kongsberg suitable wood is very cheap—an important point, when it is remembered that about 9 parts (by volume) of wood are required for 1 part of rock, and that much less skilled labour is employed for the fire-setting—as is indeed shown by the rate of wages paid. There seems to be little reason to believe that fire-setting is very unhealthy for the men employed, when care is taken to ensure efficient ventilation. No doubt the great heat developed is prejudicial ; but perhaps not more so than the dynamite smoke, the constant jar to the system in beating the drill, and the fine sharp dust often inhaled, incidental to the more modern process.

Attempts have been made at various times to improve the fire-setting method, by using turf at the Rammelsberg mines in the Harz, and brown coal in the tin stockwerks at Altenberg ; but neither were successful. Better results were obtained with coke at the St. Christoph mine near Breitenbrunn in Saxony.* At Felsobanya in Hungary, the method is improved by the firewood being held in an iron framework on legs or wheels (“pregelkatze”), which concentrates the fire and improves the draught.

According to Serlo, Hugon has used a small furnace, mounted on wheels, supplied with a blast to urge the flame direct on to the rock, at the Challanges mine in France. Burning small coals, this apparatus in

* Serlo, *Bergbaukunde*, page 326.

55 hours drove an end 4 feet wide and 6 feet high a distance of 5 feet; whilst two men with the usual explosives would only drive the same end from 5 feet to $6\frac{1}{2}$ feet in a month. If this were done at a reasonable cost, it would be a very fine result, but as to relative economy Serlo gives no particulars.

As to the possible future of the fire-setting method, it is unlikely that it will ever again come into use to any important extent; for, although it could hold its own under suitable conditions against blasting with powder, yet the modern improvement in high explosives and boring machinery, which have deprived mining through the hardest rock of all its terrors, have done away with any necessity for the old process. In exceptional cases, however, where machinery and skilled labour are not available, where fuel is cheap, and the rock very hard and siliceous—conditions which occasionally confront the mining engineer in semi-civilized countries—it would be worth while to reconsider its many advantages. By making proper arrangements, the ventilation of the workings need give no serious trouble, while the ore extracted would be more or less thoroughly roasted—an important gain in most smelting operations, or where the ore has to be subsequently crushed; and with tin or gold ores, the destruction of the pyrites and other sulphide minerals would render the subsequent dressing more easy and perfect. Indeed, in the case of refractory gold ores, the advantages of a preliminary roasting, in making more of the gold free-milling, would often compensate for a good deal of extra expense in mining underground; it is certain that the early gold-miners were quite alive to the advantages of roasting gold ores before crushing, and it is possible that in many cases a return to the ancient practice would be attended by great benefit.

It has been suggested* that fire-setting might be profitably used to enlarge a tunnel in hard rock, where a "bottom heading" had already been driven along the sole. But here the weakening of the roof and sides, owing to the great heat, would probably tell strongly against the method. It is also possible that where waste fuel is cheap, or where natural gas is available, the gas blow-pipe, urged by an air-blast, might prove of service. Such a jet would produce a very intense heat, which could be very precisely directed; but the idea does not seem ever to have been tried in practice.

Dr. C. I. E. NEVE FOSTER (Llandudno) wrote that Mr. A. L. Collins' paper would serve to remind miners of the present day that the almost

* H. S. Drinker, *Blasting, etc.* New York, 1883.

forgotten process of fire-setting had done great service in its time. He might have added that it was still in use in Burmah for quarrying jade, and in some parts of India for quarrying building-stone, as well as in Korea for gold-mining. With reference to the supposed use of vinegar, had not some one suggested that the Latin word was wrongly transcribed or wrongly translated, and that the true meaning was "axe" or "pick-axe?" In Italian nowadays the word "accetta" was used for axe. When he (Dr. Foster) visited the Kongsberg mine in 1875, he found that ample provision was made for carrying away the smoke, so that it was only the very end of the level which was filled with fumes. In one case, a large oval iron pipe (2 feet by 1½ feet) was put in near the roof, and the smoke was led away to a separate compartment of the shaft, partitioned off by a brick wall. In another instance, a channel for the smoke was made by building an arch near the roof of the level. He (Dr. Foster) must confess that he was somewhat sceptical about the advantages of fire-setting as furnishing a preliminary roasting of the ore, as suggested by Mr. Collins, who overrates the amount of oxidizing action which would take place; the fragments of ore might occasionally become glazed over, in which case the process would be the reverse of beneficial if amalgamation had to follow. It might be interesting to point out, in conclusion, that fire was used by prospectors in Siberia for sinking shafts through frozen gravel in order to reach gold-bearing alluvia.

Mr. BENNETT H. BROUGH (London) wrote that the subject of fire-setting was a particularly fascinating one, even to the dullest mining student. This was evident in a Science and Art Department examination-paper which he remembered having an opportunity of seeing some years ago. At that time, attention was being directed to the use of lime-cartidges in collieries, and the question the examiner asked was: "What methods are employed for breaking down coal when blasting cannot be applied?" To this a candidate replied that no method would be found better than the ancient method of fire-setting, in which large fires were lit against the surface of the coal, causing it to split in all directions. History does not relate whether this candidate subsequently obtained a manager's certificate. In order to see the process of fire-setting in operation, some years ago he (Mr. Brough) visited the Kongsberg mines in Norway, the Rammelsberg mine in the Hartz, and some of the Hungarian mines. Only in the first was he successful, and he could confirm the accuracy of Mr. Collins' description. In the paper there was one omission from the very full bibliographical notes, that is, a reference to a complete account of "this good and antient way of

workmanship" in that very scarce work, *A Miner's Dictionary*, written by William Hooson, a Derbyshire miner (Wrexham, 1747). Curiously enough, the process of fire-setting still survived, according to R. Helm-hacker, in Siberia, where it was used in alluvial gold-mining in combination with a sort of natural Poetsch process for sinking shafts in the watery strata. These shafts are sunk by the aid of fire in winter when the ground is frozen to a considerable depth, the wall of ice serving to support the excavation.

Mr. SOUTHERN asked if Mr. Collins could give any instances as to how far heat would penetrate into rocks? Of course he could see that it would vary according to the nature of the rock and the intensity of the fire.

The PRESIDENT thought the thanks of the meeting were due to Mr. Collins, for he had evidently worked up the subject, and gave them an insight into the ancient methods adopted. He had pleasure in proposing a vote of thanks to Mr. Collins for his interesting and valuable paper.

Mr. SOUTHERN seconded the vote, and said the paper treated the subject in a most exhaustive manner.

Mr. G. E. COLLINS said he was sure his brother would be gratified to hear of the vote of thanks accorded to him. He was afraid he could not answer Mr. Southern's question, nor did he think it was a matter of much importance, as the farther the heat went into the stone the less advantage it was. They wanted the heat to be at the surface, if the sudden cooling was to crack it off. It was impossible for a paper of this kind to include all the regions in which fire-setting had been used, and Dr. Foster had been able to add others. In a recent part of the *Transactions*, fire-setting was mentioned in regard to gold-mining in Brazil,* and he heard from his brother that there were extensive traces of its use in the Hindu Kush. The process was illustrated in nature by the scaling which took place in rocks subjected to sudden variations of temperature, and in some instances this was a very important factor in atmospheric denudation.

Mr. M. WALTON BROWN wrote, that in the Deccan, the process of stone burning was performed by a tribe called stone Waddaha, who are very skilful at it. They light fires of brushwood over the flat or convex surface of the nearly horizontal rock that crops up everywhere around, and a flake of varying thickness begins to crack off very soon. They follow the progress of the crack by listening to the sound arising when they tap the

* Vol. iv., page 220.

surface with a stone, and keep moving their fires backwards along the surface as the crack develops. With a good class of gneiss stone like that found at the Satnapilli quarries they can get out slabs of 10 or 12 feet by 4 or 5 feet by a foot thick; but the usual size for coursed rubble masonry is about $2\frac{1}{2}$ feet by $1\frac{1}{2}$ feet by $\frac{3}{4}$ foot, only of course not in so regular a shape as a parallelogram. Much of the stone used is only 4 inches thick. It comes out beautifully parallel and flat-bedded. A large stone burning business, say three or four train loads per day, requires a very extensive *bundobust* in carts for fetching in brushwood from all over the country. The quarries, too, are widely scattered, places the size of a dinner table or as large as a moderate room, scattered perhaps in scores over 40 or 50 square miles of country. Until taught how to do it, by the aid of imported Waddahs, the natives of the Kistna District had never heard of stone burning; and the very numerous and extensive remains of ancient religious dynasties which are to be found freely scattered about the country show the whole of their stone to have been either dressed boulders, or extracted from the quarry by the slow process of wedging. The thickness of the stone to be burnt out by the Waddah burners is not wholly a matter of luck. They can begin at any desired thickness by wedging a small crack at the desired depth, and this keeps cracking off fairly parallel, with, usually, a tendency to thin off somewhat. It is difficult to burn a good thick stone off the rock table in very hot weather. The cracking apparently depends on the destructive stress engendered at the plane where the heat of the fire finds itself unable to penetrate further, and where the difference of expansion of neighbouring layers is greatest. In the cold winter mornings and during the rains the result is more satisfactory. The quarries are all of gneiss stone, and the following are the results of experiments made by Prof. Unwin :—

Description of Stone.	Crushing Load per Square Inch.		Weight per Cubic Foot.
	Maximum.	Minimum.	
	Tons.	Tons.	Lbs.
Kondapilli, wedged ...	9·580	9·480	196
„ burnt ...	13·400	5·471	165
Satnapilli, burnt ...	9·210	7·470	166
Kammamet, burnt ...	7·240	4·680	178

The gneiss is susceptible of fine dressing and takes a superior polish. The Kondapilli stone is got out in rougher beds than the Satnapilli burnt

stone. The light grey Santapilli gneiss weighs about 165 pounds per cubic foot. It may usually be expected to crush under a load of 8 to 9 tons per square inch. The darker burnable Kondapilli stone was only crushed at 13·4 tons per square inch in an unexceptionally good specimen. The hard unburnable Kondapilli stone, which was wedged, is of much greater weight, and its resistance to crushing is much higher.*

Mr. H. D. Hoskold's "Notes upon a Practical Method of Ascertaining the Value or Price to be paid for Zinc Mineral" was taken as read.

* *Indian Engineering*, vol. xiii., page 473.

NOTES UPON A PRACTICAL METHOD OF ASCERTAINING
THE VALUE OR PRICE TO BE PAID FOR ZINC
MINERAL.

BY H. D. HOSKOLD.

The object of this brief paper is not to give a history of zinc-mining as carried on in various parts of the world, the amount of produce, metallurgical processes, or the geology of the rocks in which this class of mineral occurs, but merely to indicate and to place on record the practical methods followed in ascertaining the value or price which may be paid for zinc mineral.

When in Spain some years ago, the writer had an opportunity of thoroughly investigating the question and analysing the various formulæ used by the different purchasers of zinc mineral, and in order to facilitate such determinations of price as were of constant occurrence, he devised various rules, and also produced a series of tables based upon the English formula, indicating at a glance whether any or what price could be paid for zinc mineral to yield a profit under certain given conditions.

It is not to be understood that anything new or novel will be introduced; still it has occurred to the writer that what he found to be of great service to himself may also prove of some value to those who may have occasion to study the question of zinc-mining for commercial purposes.

When it has been determined that a sufficient quantity of calamine or blende mineral exists to justify a regular exploitation, some of the more important considerations will involve the question of cost of production and the assay percentage of the mineral. If it should be necessary to inspect mines situated in isolated parts of Spain, India, North America, Canada, etc., an inspection occupying a considerable period of time, and at a considerable distance from centres of population and civilization, it would be convenient to carry a few simple chemical implements in order to practise any assays which may be necessary, according to the Schaffner process by the humid way, using a solution of sulphide of sodium as a reagent in determining the assay percentage of zinc; and also oxide of iron, as an indicator to ascertain when the process is concluded, or when all the zinc has been precipitated. It is unnecessary to give the full details of this process, but the writer has found in practice that the most convenient strength for a sulphide of sodium solution is about 70 cubic centimetres to 0.5 gramme of zinc. It is also interesting to note that if iron oxide be

suspended in pure distilled water, about 0·6 cubic centimetre of sulphide of sodium solution will be required for every 100 cubic centimetres of water to colour the iron black ; therefore 0·6 cubic centimetre for every 100 of sodium solution is deducted from the total number of cubic centimetres of sulphide of sodium used in the assay operation.

The Vieille Montagne Company produces a very considerable quantity of zinc mineral from its mines situated in the Picos de Europa, Spain, and the formula adopted in determining the price to be paid to other zinc-mineral producers is as follows:—

$$V = (R - E) (P - T) + \frac{(R - E) D}{2},$$

in which

V = the value of a ton of mineral.

R = percentage of the mineral per volumetric assay.

E = discount of the anterior percentage for the loss which takes place in the treatment of the mineral in the furnace, which is 11 per cent. in the crude mineral, 15 in the calcined, and 17 when the quantity of silicate exceeds 15 per cent.

P = price of 1 kilogramme of zinc when the current price is 45 francs per 100 kilogrammes.

T = expense of the metallurgical treatment per ton of mineral, which is fixed at 80 francs.

D = difference between the price of 45 francs per 100 kilogrammes of zinc which we have supposed and the value which it has when the calculation is made, with the understanding that the value of 1 kilogramme has always to be taken.

A second formula, employed by the intermediate agents or Antwerp buyers, is as follows :—

$$V = \left(\frac{T - \frac{T}{8}}{10} \right) (P - 2\cdot50) - 60,$$

and is thus practically illustrated :—

Supposing that the price of spelter in London is, say, £18 per ton, and the exchange at the rate of 25·20 francs,

	Francs.
Then £18 × 25·20	453·60
Less 1·5 per cent. to reduce ton of 1,015 kilos to 1,000 kilos	6·80
Per 1,000 kilogrammes	446·80
Per 100 „	44·68
Less 2·50 francs	2·50
Per 100 kilos	42·18

Supposing the ore to contain 50 per cent., this, less $\frac{1}{2}$, according to the formula, would leave :—

	Francs.
$\frac{40\% \times 42.18 \text{ francs}}{10}$	= 168.72
Deduct cost of smelting	= 60.00
Value of 1,000 kilogrammes of ore—cost, insurance, and } freight—delivered <i>ex</i> ship Antwerp	= 108.72

The following formula is also employed on the Continent by agents purchasing zinc ores :—

$$V = \left(\frac{T - \frac{1}{2} + 1}{10} \right) (P - 5\%) - 65 \text{ francs.}$$

In order to obtain a profit from the sellers and also from the smelters of zinc mineral, the intermediate purchasing agents have the practice of varying some of the elements constituting the formulæ, but it is obvious that the best price would be obtained when the mining producers sell their crude mineral direct to the smelters.

When blende ores contain less than 5 per cent. of lead the smelter's charge is raised from 65 to 85 francs per ton for, as it is termed, "return charges" for the reduction.

The principal purchasers of zinc mineral in Swansea employ the following rule in estimating the price which may be paid per ton for such ores:—

Rule—From 100 deduct the calcination-loss and divide the assay, less 1 unity, by the result. From the answer deduct $\frac{1}{2} + 1$. Multiply the remainder by the London quotation price for spelter per ton, less £1, and divide by 100. Deduct return charges for smelting, or £2 10s., also deduct calcination-percentage or loss value, and also 5s. per ton, cost of calcination.

Thus, supposing calamine ore would assay, say 40 per cent. with a calcination-loss of say 30 per cent., spelter being at the rate of £17 per ton in London, we should have:—

	$100 - 30 = 70\%$; and $40 - 1 = 39\%$;
Also $\frac{39 \times 100}{70}$	$= 55.7\%$; then $55.7 - \frac{1}{2} = 44.6 - 1 = 43.6\%$.
And $\frac{43.6 \times £16}{100}$	= £6 19 6
Less return charges	= 2 10 0
Calcination loss at 30 % of £4.9s. 6d.	= 4 9 6
	= 1 6 10
	= 3 2 8
Deduct cost of calcination per ton... ..	= 0 5 0
Total value or price per ton of crude calamine, <i>ex</i> }	
ship at Swansea, dry weight	= £2 17 8

Taking the preceding assay and loss due to calcination, and if it were required to determine the total weight of calamine necessary to make up one ton of calcined ore at the rate of 57·1428 per cent., we should have:—

$$\frac{20 \times 100}{70} = 28·5714 \text{ cwts.}$$

The proof of the percentage of the calcined mineral is:—

$$\frac{40 \times 100}{70} = 57·1428 \text{ per cent.}$$

The excess of the percentage due to the extra weight of 8·5714 cwts. of crude mineral would be:—

$$\frac{57·1428 \times 30}{100} = 17·1428 \text{ per cent.}$$

and 40 % + 17·1428 % = 57·1428 %, as previously indicated.

If it were required to ascertain what percentage of crude mineral would produce 57·1428 per cent. under the above conditions, we should also have

$$\frac{57·1428 \times 70}{100} = 39·99999 \text{ per cent,}$$

or practically 40 per cent. as proposed.

It may be observed, under the conditions proposed, that 28·5714 cwts. of crude ore at 40 per cent. would produce 20 cwts. of calcined mineral at the rate of 57·1428 per cent.: but the price of 20 cwts. at 40 per cent., excluding the cost of calcination, is £3 2s. 8d. per ton for crude mineral, and 28·5714 cwts. at £3 2s. 8d. per ton would be worth a gross sum of £4 9s. 6½d., and deducting 7s. 1½d. for calcination, would leave the net price £4 2s. 4¾d., but these conditions refer to a sale of the mineral in a crude condition. Then the question arises whether the difference between the cost of transport of 28·5714 cwts. against 20 cwts. of calcined mineral, and the cost of calcination, would be sufficient to justify the calcining operation being carried on at, or in the vicinity of the mines. Naturally, this would involve a consideration of the facilities afforded and the cost of labour and fuel, which may vary under different circumstances; but, supposing that the calcination be carried on by the proprietor of the mine in one place and also by the purchaser of the mineral in another under similar conditions of cost, the mining proprietor would appear to gain nothing by the calcination, but only the difference in the cost of transporting 28·5714 cwts. of crude mineral, as against 20 cwts. of calcined mineral, because there is no more metal in the 20 cwts. of calcined ore at 57·1428 per cent. than existed in the 28·5714 cwts. at the rate of 40 per cent. For:—

	£	s.	d.	£	s.	d.
The gross selling price of 28·5714 cwts. crude ore						
at 40 per cent. is				4	9	6½
Deducting purchaser's cost for calcination ...				0	7	1½
				4	2	4½
Price paid for 20 cwts. of calcined mineral yielding						
at the rate of 57·1428 per cent.... ..	4	2	4½			
Extra price allowed and paid by purchaser to						
mining proprietor for the calcination of						
28·5714 cwts. of crude ore	0	7	1½			
Total price paid by the purchaser ...	4	9	6½			
But the sum of 7s. 1½d. has to be expended by the						
mining proprietor for the calcination of the						
mineral—therefore, deducting it	0	7	1½			
					4	2 4½
Difference in selling price... ..						nil

roving that under the circumstances the price received in the two cases is the same.

Supposing the freight and insurance on delivery in Swansea is 12s. 9d. per ton, the price paid in Spain in 1891, the cost of 28·5714 cwts. of crude ore would be 17s. 4½d., or a difference in favour of reducing the weight by calcination of 4s. 7½d. per ton, so that it would appear that a mineral which could not be extracted from a mine, at a profit, if sold in the crude condition, may be made to do so if calcined at a cost equal to, or not much in excess of, that allowed by the purchaser for the same operation.

Naturally, the mineral should be delivered in a dry condition, but if it is otherwise it may be subjected to a reduction for humidity.

When there are a very large number of assays and resulting calculations to be made by the inspecting engineer when examining the mines, or at the nearest convenient point to them, it would be advantageous to collect all the details as exhibited in the following tabular form.

The elements contained in columns Nos. 2 and 3 consist of a portion of a long series of assays made by the writer when in Spain in 1879.

The calculated quantities in columns Nos. 4, 5, 6, and 7 respectively were determined by the foregoing rules, and were employed in another class of computations required for the determination of the commercial present value of the zinc mines then under consideration.

CALCULATED DETAILS.

No of Assay.	Percentage of Ore in the Assays	Percentage of Loss by Calcination.	Weight of Crude Ore required to make up 1 Ton of Calcined Ore.			Weight of Calcined Ore derived from Weight in Column No. 4.			Weight of Metal in every 20 Cwt. of Calcined Ore.			Total Percentage of Metal in the Ore after Calcination.
			Cwt.	Qrs.	Lbs.	Cwt.	Qrs.	Lbs.	Cwt.	Qrs.	Lbs.	
1	34.13	26.70	20	0	0	14	3	5.600	6	3	5.60	34.13
			7	0	2.912	5	0	22.315	2	1	15.55	11.94
			27	0	2.912	19	3	27.915	9	0	21.15	46.07
2	42.66	30.10	20	0	0	14	3	5.600	8	1	16	42
			7	0	2.912	5	0	22.315	2	3	22.503	14.70
			27	0	2.912	19	3	27.915	11	1	10.503	56.70
3	43.20	29.75	20	0	0	14	0	22.400	8	0	18.816	43
			8	0	18.816	5	3	4.556	3	2	1.370	17.56
			28	0	18.816	19	3	26.956	11	2	20.186	60.56
4	46.93	25.00	20	0	0	15	0	0	9	1	16.800	47
			6	2	18.592	4	3	27.944	3	0	14.898	15.66
			26	2	18.592	19	3	27.944	12	2	3.698	62.66
5	46.93	31.50	20	0	0	13	3	5.60	9	1	16.80	47
			8	3	26.208	6	0	22.348	4	0	24.917	21.11
			28	3	26.208	19	3	27.948	13	2	13.717	68.11
6	43.20	30.90	20	0	0	13	3	5.60	8	2	11.200	43
			8	3	26.208	6	0	22.284	3	3	12.669	19.31
			28	3	26.208	19	3	27.884	12	1	23.869	62.31
7	43.20	28.90	20	0	0	14	0	22.40	8	2	11.200	43
			8	0	18.816	5	3	5.520	3	2	1.371	17.56
			28	0	18.816	19	3	27.920	12	0	12.571	60.56
8	44.80	30.95	20	0	0	13	3	5.600	9	0	0	45
			8	3	25.21	6	0	21.595	4	0	4.345	20.19
			28	3	25.21	19	3	27.195	13	0	4.345	65.19
9	41.60	28.75	20	0	0	14	1	16.800	8	0	22.400	41
			7	3	2.912	5	2	11.056	3	0	22.074	16.02
			27	3	2.912	19	3	27.856	11	1	16.474	57.02
10	50.66	32.50	20	0	0	13	2	11.20	10	0	0	50
			9	1	17.92	6	1	16.67	4	2	22.96	23.52
			29	1	17.92	19	3	27.87	14	2	22.96	73.52

The following tables are a portion of a series calculated according to the principles laid down in the English formula, and would be of considerable service, supposing the conditions are now the same as they were when the tables were constructed; if not they may serve as a model for the construction of others when the variable elements employed, such as the price of spelter, cost of exploitation and transport have been determined.

Under the conditions of Table No. 1 there would appear to be very

little or no profit upon mineral of less than 34 per cent. with a calcination loss of 26 per cent. It would, however, be a question for the exploiters of a mine to ascertain for themselves whether they would be satisfied with a profit to be derived from a less percentage of ore presented under the conditions exhibited in the tables from No. 1 to No. 9.

It was not considered of importance or advantage to introduce the remaining series of tables of this class in the possession of the writer.

When zinc mines are situated at a long distance from centres of population and railway communication, in elevated places like the Picos de Europa and others, in Spain, and the roads are long, tortuous, and difficult, the transport of the mineral from such mines to calcining-kilns at lower levels, the unloading, reloading after calcination with probably extra transport from the kilns to store-houses at the nearest shipping-place, becomes very costly. Such expenses are included in the sums which form column No. 5 of the tables.

Taking for example the first table under No. 16, and assuming that the cost of extracting the ore is no more than 11d. per cwt. Column 3 with an assay-produce of 49 per cent. of metal and 35 per cent. calcination-loss, the total cost of extraction amounts to 18s. 4d. per ton, which deducted from £2 4s. in column 5 leaves £1 5s. 8d. per ton, to cover all expenses and contingencies due to the transport of the mineral to a place of shipment.

The same conditions would exist whether a zinc-mining proprietor were to sell his ore direct to the smelters or foreign purchaser, or to an intermediate purchasing agent, with a probable result that he may gain more by the former than the latter plan. However, in the latter case, it is assumed that a profit would be included in the 11d. per cwt. or whatever other price may be agreed upon. If, however, it did not exist, then the intermediate purchasing agent's net profit of £1 6s. 6½d. per ton, column 8, would have to be reduced to suit the circumstances or demand of the mining proprietor.

The calculated net profit of £1 6s. 6½d. per ton proves that it would be exceedingly inconvenient and injurious to the original mineral producer to allow the intervention of an intermediate purchasing agent, who, in such a case would become a speculator on the bounty and possibly ignorance of the original miner or ore-producer.

When small mines are worked with inadequate capital, and only at intervals, and the production is very limited, and the owner has no personal knowledge of, or confidence in, foreign smelting purchasers, small parcels of zinc ore used to be sold to local agents in the manner indicated, and doubtless the custom is still continued.

CALCULATIONS UPON CRUDE CALAMINE ORE.

Spelter—£16 in Swansea, £17 in London. Weight to be 112 lbs. per English cwt.
Freight and Insurance, 12s. 9d. per ton.

TABLE NO. 1.

No.	Per-centage of Ore.	Loss by Calci-nation.	Cost per 112 lbs. English Cwt.	Total Cost on Board.	Total Cost at Swansea.	Gross Value per Ton.	Net Profit per Ton.
			d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1	34	26	7½	1 9 0	2 1 9	2 0 1½	*0 1 7½
2	35	26	7½	1 9 0	2 1 9	2 2 8	0 0 11
3	36	26½	7¼	1 9 0	2 1 9	2 5 5½	0 3 8½
4	37	26	7½	1 9 0	2 1 9	2 8 3½	0 6 6½
5	38	27½	7½	1 9 0	2 1 9	2 11 1½	0 9 4½
6	39	28	7½	1 9 0	2 1 9	2 13 11½	0 12 2½
7	40	28½	7¼	1 9 0	2 1 9	2 16 9½	0 15 0½
8	41	29	7½	1 9 0	2 1 9	2 19 7½	0 17 10½
9	42	29	7¼	1 9 0	2 1 9	3 2 2½	1 0 5½
10	43	30	7½	1 10 0	2 2 9	3 5 3½	1 2 6½
11	44	31	8	1 12 0	2 4 9	3 8 4½	1 3 7½
12	45	32	8½	1 14 0	2 6 9	3 11 5½	1 4 8½
13	46	33	9	1 16 0	2 8 9	3 14 6½	1 5 9½
14	47	33	9½	1 18 0	2 10 9	3 17 1½	1 6 4½
15	48	35	10½	2 2 0	2 14 9	4 0 8½	1 5 11½
16	49	35	11	2 4 0	2 16 9	4 3 3½	1 6 6½
17	50	35	11½	2 6 0	2 18 9	4 5 11½	1 7 2½
18	51	35	12	2 8 0	3 0 9	4 8 5	1 7 8

TABLE NO. 2.

1	34	26	7½	1 10 0	2 2 9	2 0 1½	*0 2 7½
2	35	26	7½	1 10 0	2 2 9	2 2 8	*0 0 1
3	36	26½	7½	1 10 0	2 2 9	2 5 5½	0 2 8½
4	37	27	7½	1 10 0	2 2 9	2 8 3½	0 5 6½
5	38	27½	7½	1 10 0	2 2 9	2 11 1½	0 8 4½
6	39	28	7½	1 10 0	2 2 9	2 13 11½	0 11 2½
7	40	28½	7½	1 10 0	2 2 9	2 16 9½	0 14 0½
8	41	29	7½	1 10 0	2 2 9	2 19 7½	0 16 10½
9	42	29	7½	1 10 0	2 2 9	3 2 2½	0 19 5½
10	43	30	7½	1 11 0	2 3 9	3 5 3½	1 1 6½
11	44	31	8¼	1 13 0	2 5 9	3 8 4½	1 2 7½
12	45	32	8½	1 15 0	2 7 9	3 11 5½	1 3 8½
13	46	33	9½	1 17 0	2 9 9	3 14 6½	1 4 9½
14	47	33	9½	1 19 0	2 11 9	3 17 1½	1 5 4½
15	48	35	10½	2 3 0	2 15 9	4 0 8½	1 4 11½
16	49	35	11½	2 5 0	2 17 9	4 3 3½	1 5 6½
17	50	35	11½	2 7 0	2 19 9	4 5 11½	1 6 2½
18	51	35	12½	2 9 0	3 1 9	4 8 5	1 6 8

* Loss.

CALCULATIONS UPON CRUDE CALAMINE ORE.—*Continued.*

Spelter—£16 in Swansea, £17 in London. Weight to be 112 lbs. per English cwt.
Freight and Insurance, 12s. 9d. per ton.

TABLE NO. 3.							
No.	Per-centage of Ore.	Loss by Calci-nation.	Cost per 112 lbs. English Cwt.	Total Cost on Board.	Total Cost at Swansea.	Gross Value per Ton.	Net Profit per Ton.
1	34	26	d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
2	35	26	7½	1 11 0	2 3 9	2 0 1½	*0 3 7½
3	36	26·5	7½	1 11 0	2 3 9	2 2 8	*0 1 1
4	37	27	7½	1 11 0	2 3 9	2 5 5½	0 1 8½
5	38	27·5	7½	1 11 0	2 3 9	2 8 3½	0 4 6½
6	39	28	7½	1 11 0	2 3 9	2 11 1½	0 7 4½
7	40	28·5	7½	1 11 0	2 3 9	2 13 11½	0 10 2½
8	41	29	7½	1 11 0	2 3 9	2 16 9½	0 13 0½
9	42	29	7½	1 11 0	2 3 9	2 19 7½	0 15 10½
10	43	30	8	1 12 0	2 4 9	3 2 2½	0 18 5½
11	44	31	8½	1 12 0	2 4 9	3 5 3½	1 0 6½
12	45	32	9	1 14 0	2 6 9	3 8 4½	1 1 7½
13	46	33	9½	1 16 0	2 8 9	3 11 5½	1 2 8½
14	47	33	10	1 18 0	2 10 9	3 14 6½	1 3 9½
15	48	35	11	2 0 0	2 12 9	3 17 1½	1 4 4½
16	49	35	11½	2 4 0	2 16 9	4 0 8½	1 3 11½
17	50	35	12	2 6 0	2 18 9	4 3 3½	1 4 6½
18	51	35	12½	2 8 0	3 0 9	4 5 11½	1 5 2½
				2 10 0	3 2 9	4 8 5	1 5 8
TABLE NO. 4.							
1	34	26	8	1 12 0	2 4 9	2 0 1½	*0 4 7½
2	35	26	8	1 12 0	2 4 9	2 2 8	*0 2 1
3	36	26·5	8	1 12 0	2 4 9	2 5 5½	0 0 8½
4	37	27	8	1 12 0	2 4 9	2 8 3½	0 3 6½
5	38	27·5	8	1 12 0	2 4 9	2 11 1½	0 6 4½
6	39	28	8	1 12 0	2 4 9	2 13 11½	0 9 2½
7	40	28·5	8	1 12 0	2 4 9	2 16 9½	0 12 0½
8	41	29	8	1 12 0	2 4 9	2 19 7½	0 14 10½
9	42	29	8	1 12 0	2 4 9	3 2 2½	0 17 5½
10	43	30	8½	1 13 0	2 5 9	3 5 3½	0 19 6½
11	44	31	8½	1 15 0	2 7 9	3 8 4½	1 0 7½
12	45	32	9½	1 17 0	2 9 9	3 11 5½	1 1 8½
13	46	33	9½	1 19 0	2 11 9	3 14 6½	1 2 9½
14	47	33	10½	2 1 0	2 13 9	3 17 1½	1 3 4½
15	48	35	11½	2 5 0	2 17 9	4 0 8½	1 2 11½
16	49	35	11½	2 7 0	2 19 9	4 3 3½	1 3 6½
17	50	35	12½	2 9 0	3 1 9	4 5 11½	1 4 2½
18	51	35	12½	2 11 0	3 3 9	4 8 5	1 4 8

* Loss.

CALCULATIONS UPON CRUDE CALAMINE ORE.—Continued.

Spelter—£16 in Swansea, £17 in London. Weight to be 112 lbs. per English cwt.
Freight and Insurance. 12s. 9d. per ton.

TABLE No. 5.

No.	Per-centage of Ore.	Loss by Calci-nation.	Cost per 112 lbs. English Cwt.	Total Cost on Board.	Total Cost at Swansea.	Gross Value per Ton.	Net Profit per Ton.
			d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1	34	26	8½	1 13 0	2 5 9	2 0 1½	*0 5 7½
2	35	26	8½	1 13 0	2 5 9	2 2 8	*0 3 1
3	36	26½	8½	1 13 0	2 5 9	2 5 5½	*0 0 3½
4	37	27	8½	1 13 0	2 5 9	2 8 3½	0 2 6½
5	38	27½	8½	1 13 0	2 5 9	2 11 1½	0 5 4½
6	39	28	8½	1 13 0	2 5 9	2 13 11½	0 8 2½
7	40	28½	8½	1 13 0	2 5 9	2 16 9½	0 11 0½
8	41	29	8½	1 13 0	2 5 9	2 19 7½	0 13 10½
9	42	29	8½	1 13 0	2 5 9	3 2 2½	0 16 5½
10	43	30	8½	1 14 0	2 6 9	3 5 3½	0 18 6½
11	44	31	9	1 16 0	2 8 9	3 8 4½	0 19 7½
12	45	32	9½	1 18 0	2 10 9	3 11 5½	1 0 8½
13	46	33	10	2 0 0	2 12 9	3 14 6½	1 1 9½
14	47	33	10½	2 2 0	2 14 9	3 17 1½	1 2 4½
15	48	35	11½	2 6 0	2 18 9	4 0 8½	1 1 11½
16	49	35	12	2 8 0	3 0 9	4 3 3½	1 2 6½
17	50	35	12½	2 10 0	3 2 9	4 5 11½	1 3 2½
18	51	35	13	2 12 0	3 4 9	4 8 5	1 3 8

TABLE No. 6.

1	34	26	8½	1 14 0	2 6 9	2 0 1½	*0 6 7½
2	35	26	8½	1 14 0	2 6 9	2 2 8	*0 4 1
3	36	26½	8½	1 14 0	2 6 9	2 5 5½	*0 1 3½
4	37	27	8½	1 14 0	2 6 9	2 8 3½	0 1 6½
5	38	27½	8½	1 14 0	2 6 9	2 11 1½	0 4 4½
6	39	28	8½	1 14 0	2 6 9	2 13 11½	0 7 2½
7	40	28½	8½	1 14 0	2 6 9	2 16 9½	0 10 0½
8	41	29	8½	1 14 0	2 6 9	2 19 7½	0 12 10½
9	42	29	8½	1 14 0	2 6 9	3 2 2½	0 15 5½
10	43	30	8½	1 15 0	2 7 9	3 5 3½	0 17 6½
11	44	31	9½	1 17 0	2 9 9	3 8 4½	0 18 7½
12	45	32	9½	1 19 0	2 11 9	3 11 5½	0 19 8½
13	46	33	10½	2 1 0	2 13 9	3 14 6½	1 0 9½
14	47	33	10½	2 3 0	2 15 9	3 17 1½	1 1 4½
15	48	35	11½	2 7 0	2 19 9	4 0 8½	1 0 11½
16	49	35	12½	2 9 0	3 1 9	4 3 8½	1 1 6½
17	50	35	12½	2 11 0	3 3 9	4 5 11½	1 2 2½
18	51	35	13½	2 13 0	3 5 9	4 8 5	1 2 8

* Loss.

CALCULATIONS UPON CRUDE CALAMINE ORE.—*Continued.*

Spelter—£16 in Swansea, £17 in London. Weight to be 112 lbs. per English cwt.
Freight and Insurance, 12s. 9d. per ton.

TABLE No. 7.

No.	Per-centage of Ore.	Loss by Calci-nation.	Cost per 112 lbs. English Cwt.	Total Cost on Board.	Total Cost at Swansea.	Gross Value per Ton.	Net Profit per Ton.
			d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
1	34	26	8½	1 15 0	2 7 9	2 0 1¼	*0 7 7½
2	35	26	8½	1 15 0	2 7 9	2 2 8	*0 5 1
3	36	26·5	8½	1 15 0	2 7 9	2 5 5½	*0 2 3½
4	37	27	8½	1 15 0	2 7 9	2 8 3½	0 0 6½
5	38	27·5	8½	1 15 0	2 7 9	2 11 1½	0 3 4½
6	39	28	8½	1 15 0	2 7 9	2 13 11½	0 6 2½
7	40	28·5	8½	1 15 0	2 7 9	2 16 9½	0 9 0½
8	41	29	8½	1 15 0	2 7 9	2 19 7½	0 11 10½
9	42	29	8½	1 15 0	2 7 9	3 2 2¼	0 14 5¼
10	43	30	9	1 16 0	2 8 9	3 5 3½	0 16 6½
11	44	31	9½	1 18 0	2 10 9	3 8 4½	0 17 7½
12	45	32	10	2 0 0	2 12 9	3 11 5½	0 18 8½
13	46	33	10½	2 2 0	2 14 9	3 14 6½	0 19 9½
14	47	33	11	2 4 0	2 16 9	3 17 1½	1 0 4½
15	48	35	12	2 8 0	3 0 9	4 0 8½	0 19 11½
16	49	35	12½	2 10 0	3 2 9	4 3 3½	1 0 6½
17	50	35	13	2 12 0	3 4 9	4 5 11¼	1 1 2¼
18	51	35	13½	2 14 0	3 6 9	4 8 5	1 1 8

TABLE No. 8.

1	34	26	9	1 16 0	2 8 9	2 0 1¼	*0 8 7½
2	35	26	9	1 16 0	2 8 9	2 2 8	*0 6 1
3	36	26·5	9	1 16 0	2 8 9	2 5 5½	*0 3 3½
4	37	27	9	1 16 0	2 8 9	2 8 3½	*0 0 5½
5	38	27·5	9	1 16 0	2 8 9	2 11 1½	0 2 4½
6	39	28	9	1 16 0	2 8 9	2 13 11½	0 5 2½
7	40	28·5	9	1 16 0	2 8 9	2 16 9½	0 8 0½
8	41	29	9	1 16 0	2 8 9	2 19 7½	0 10 10½
9	42	29	9	1 16 0	2 8 9	3 2 2¼	0 13 5½
10	43	30	9½	1 17 0	2 9 9	3 5 3½	0 15 6½
11	44	31	9½	1 19 0	2 11 9	3 8 4½	0 16 7½
12	45	32	10½	2 1 0	2 13 9	3 11 5½	0 17 8½
13	46	33	10½	2 3 0	2 15 9	3 14 6½	0 18 9½
14	47	33	11½	2 5 0	2 17 0	3 17 1½	0 19 4½
15	48	35	12½	2 9 0	3 1 9	4 0 8½	0 18 11½
16	49	35	12½	2 11 0	3 3 9	4 3 3½	0 19 6½
17	50	35	13½	2 13 0	3 5 9	4 5 11¼	1 0 2¼
18	51	35	13½	2 15 0	3 7 9	4 8 5	1 0 8

CALCULATIONS FROM OTHER CALCULATIONS ONLY.—Continued.

Spices— $\$24$ in Swansen, $\$27$ in London. Weight to be 112 lbs. per English cwt.
Freight and Insurance, 1 lb. 3d. per ton.

TABLE No. 2.

No.	Per-centage of Ton.	Cost of Transportation.	Cost per 112 lbs. English Cwt.	Total Cost in Board.	Total Cost in Swansen.	Gross Value per Ton.	Net Profit per Ton.
1	34	35	9 $\frac{1}{2}$	2 4 1	2 4 1	2 4 1	2 4 1
2	35	35	9 $\frac{1}{2}$	2 17 0	2 9 9	2 0 1 $\frac{1}{2}$	0 9 7 $\frac{1}{2}$
3	36	35 $\frac{1}{2}$	9 $\frac{1}{2}$	2 17 0	2 9 9	2 2 8	0 7 1
4	37	37	9 $\frac{1}{2}$	2 17 0	2 9 9	2 5 5 $\frac{1}{2}$	0 4 3 $\frac{1}{2}$
5	38	37 $\frac{1}{2}$	9 $\frac{1}{2}$	2 17 0	2 9 9	2 8 3 $\frac{1}{2}$	0 1 5 $\frac{1}{2}$
6	39	38 $\frac{1}{2}$	9 $\frac{1}{2}$	2 17 0	2 9 9	2 11 1 $\frac{1}{2}$	0 1 4 $\frac{1}{2}$
7	40	39 $\frac{1}{2}$	9 $\frac{1}{2}$	2 17 0	2 9 9	2 13 11 $\frac{1}{2}$	0 4 2 $\frac{1}{2}$
8	41	40 $\frac{1}{2}$	9 $\frac{1}{2}$	2 17 0	2 9 9	2 16 9 $\frac{1}{2}$	0 7 0 $\frac{1}{2}$
9	42	41 $\frac{1}{2}$	9 $\frac{1}{2}$	2 17 0	2 9 9	2 19 7 $\frac{1}{2}$	0 9 10 $\frac{1}{2}$
10	43	42 $\frac{1}{2}$	9 $\frac{1}{2}$	2 17 0	2 9 9	3 2 2 $\frac{1}{2}$	0 12 5 $\frac{1}{2}$
11	44	43 $\frac{1}{2}$	10	2 0 0	2 12 9	3 8 4 $\frac{1}{2}$	0 15 7 $\frac{1}{2}$
12	45	44 $\frac{1}{2}$	10	2 0 0	2 12 9	3 8 4 $\frac{1}{2}$	0 15 7 $\frac{1}{2}$
13	46	45 $\frac{1}{2}$	11	2 4 0	2 16 9	3 14 6 $\frac{1}{2}$	0 17 9 $\frac{1}{2}$
14	47	46 $\frac{1}{2}$	11 $\frac{1}{2}$	2 6 0	2 18 9	3 17 1 $\frac{1}{2}$	0 18 4 $\frac{1}{2}$
15	48	47 $\frac{1}{2}$	12 $\frac{1}{2}$	2 10 0	3 2 9	4 0 8 $\frac{1}{2}$	0 17 11 $\frac{1}{2}$
16	49	48 $\frac{1}{2}$	13	2 12 0	3 4 9	4 3 3 $\frac{1}{2}$	0 18 6 $\frac{1}{2}$
17	50	49 $\frac{1}{2}$	13 $\frac{1}{2}$	2 14 0	3 6 9	4 5 11 $\frac{1}{2}$	0 19 2 $\frac{1}{2}$
18	51	50 $\frac{1}{2}$	14	2 16 0	3 8 9	4 8 5	0 19 8

* Low.

The meeting then adjourned.

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FEDERATED INSTITUTION OF MINING ENGINEERS.

GENERAL MEETING,

HELD IN THE ROOMS OF THE INSTITUTION OF CIVIL ENGINEERS, 25, GREAT
GEORGE STREET, WESTMINSTER, JUNE 2ND, 1893.

MR. GEORGE LEWIS, PRESIDENT, IN THE CHAIR.

The following paper, by M. Marcel Bertrand, was read on "The
Correlation of the Coal-fields of Northern France and Southern
England":—

THE CORRELATION OF THE COAL-FIELDS OF NORTHERN FRANCE AND SOUTHERN ENGLAND.*

BY MARCEL BERTRAND, CHIEF ENGINEER OF MINES, PROFESSOR OF
GEOLOGY IN THE FRENCH SCHOOL OF MINES.

I. INTRODUCTORY REMARKS.

The discovery of coal at Dover, apart from its industrial importance, is of commanding interest from the geological point of view. It amply confirms the truth of the ideas to which Godwin-Austen gave expression in 1855, and the conclusions of many British geologists who followed in his footsteps. The principle from which Godwin-Austen proceeded is summed up in the axiom that recent folds are formed along the same lines as ancient folds. The correctness of this axiom once established, an attentive study of the surface of a given area will enable the observer to trace out and follow the axis of the ancient folds or convolutions, even when they are masked by more recent and unconformable strata. In particular are we thus enabled to determine along what lines we had best look for the continuation of known coal-basins. It may be well to add that the continuations of these basins will not necessarily yield coal, for they may be more or less extensively denuded; but we can at any rate affirm that along the axis of these basins lie the most promising localities for the search of the mineral.

The Somerset coal-basin is limited southward by the arch of the Mendips, which itself sinks eastward beneath the Jurassic rocks. These in turn form an arch, a gentler arch, which is prolonged still eastward south of London and Dover, into the Cretaceous rocks, and is, so to speak, emphasized by the ridge of the North Downs. Hence the conclusion seemed reasonable that the continuation of the Somerset coal-basin, if such a continuation existed, should be found forward of that line; and now the hypothesis is confirmed by the results of the Dover boring.

Godwin-Austen had further remarked that the axis of the North Downs was continued on the other side of the English Channel by the axis of Artois, that is, by the anticlinal arch of Cretaceous rocks which

* Translated by L. L. Belinfante, B. Sc.

forms the southern limit of the Franco-Belgian coal-basin. Therefore it was concluded that the Somerset basin and its presumed continuations formed the direct prolongation of the Belgian coal-field. But the study of the rocks of Boulonnais has long since led French geologists to express doubts as to the validity of that conclusion. Coal-measures occur at Hardingham and Ferques; but if these restricted outcrops be regarded as continuing the Pas-de-Calais basin (Lens, Auchy-au-Bois, Fléchinelle), the line thus traced out would run far south of Dover. In which case the result of the Dover boring would prove that in this area there are at least two distinct synclinal folds, both of which, over some extent of their course, yield coal.

The facts now ascertained enable us to enter more fully into the question than was at all possible thirty years ago. On the one hand, they furnish fresh arguments in favour of Godwin-Austen's principle; and on the other, they certainly tend to show that there are in all probability three distinct synclinal folds, along whose track coal is locally known, and along which one may well hope, therefore, to find the mineral again and again.

These folds may be enumerated as follows:—Firstly, that of Dover corresponding to the Somerset basin, and perhaps also to the northern part of the Belgian coal-basin. Secondly, that of Hardingham, corresponding to the northern part of the Pas-de-Calais coal-basin; and thirdly, a more southerly fold, corresponding to the southern part of the Pas-de-Calais coal-basin, and the outcrops of Auchy-au-Bois and Fléchinelle.

On this hypothesis the Belgian coal-basin branches out westwards into a series of other basins, some of which at least (Dover and Hardingham) are only here and there, as it were momentarily, unproductive.

II. GODWIN-AUSTEN'S PRINCIPLE—RECURRENCE OF FOLDS ALONG THE SAME LINES.

Godwin-Austen's principle did not flash entirely unawares upon the geological mind in his 1855 paper. Murchison had already remarked that "other parallel outbursts and upheavals have naturally taken place along the same lines . . . (those of least resistance) . . . at subsequent epochs."* Dana, and in his train, many geologists among his fellow-countrymen, generalized the idea so as to make of it the basis of their conceptions of American geology; while in France, where Élie de Beaumont himself had time and again appealed to the principle of

* *Geology of Russia*, page 469.

recurrences, M. Jourdy as early as 1871, based on the same idea (re-christened for the nonce "law of position") the theory which he brought forward in opposition to the famous "pentagonal system" [sub-division of the earth's surface]. Nevertheless, Godwin-Austen's name is deservedly attached to the above-mentioned principle, for he was the first to enunciate the axiom in terms sufficiently precise to make of it an instrument of research. One is fain to admit, however, that his arguments were far from adequate for the final settlement of the question. They are confined to the study of the anticlinal fold which forms the southward limit of the coal-basins. In France the axis of Artois continues the Palæozoic axes of the Northern Ardennes, while in England the axis of the North Downs continues that of the Mendips: so much for the main idea. The original appellation has been extended to the various tectonic phenomena (or geological "features") noted at different points of that chain of axes, without sufficiently considering the evidence for their continuity. In fact we are here only dealing, as it were, with a preliminary sketch, whereas we look for a complete outline. And moreover the bearing of Godwin-Austen's remarks on the thickening, or, as the case may be, the thinning away of the Cretaceous or the Tertiary strata opposite the points where the coal-band becomes thicker or thinner, is at any rate rather questionable. When, therefore, Godwin-Austen concludes that between the older line of disturbance and the newer there is not only a general coincidence of direction, but a close resemblance in various geological features and structural details, his conclusion must be regarded as premature. The coincidence was, as Mr. Gosselet has recently said, amply sufficient to demonstrate the probability of the main hypothesis; but it would be by no means sufficient to convert that probability into an absolute certainty, although the case is strengthened by the results of the Kentish Town and Dover borings.

III. GENERAL CONCORDANCE OF THE SYSTEMS OF ANCIENT AND RECENT FOLDS.

But in our day a change has come over the scene, and the mere probable hypothesis has been experimentally confirmed at so many points that the cumulative mass of evidence may be considered as constituting an irrefutable proof.

In the first place, a new argument of capital importance has been brought to the front, thanks to a more exhaustive study of Palæozoic folds and Tertiary undulations.

For many a long year observers were accustomed to examine separately

the various Palæozoic massifs, while the possibility of correlating over great distances the folds which they saw in these massifs never entered their heads. Devonshire and Brittany, the Central Plateau of France and the Ardennes, the Vosges and the Harz, and the Bohemian mountains were looked upon as so many individual units, and the only relationship which it was sought to establish between them was that of the composition of the different strata. Suess, the brilliant Vienna professor, was the first to show that these now isolated massifs are the solitary remnants of a single great chain which ranged right across Central and Western Europe till the end of the Primary epoch. It was formed, like the Alps of our time, by a series of minor, roughly parallel ranges; or, in other words, by a series of folds whose axes followed each other at short intervals, keeping a parallel alignment in the fairly rectilinear portions, or concentric one within the other in the curvilinear portions.

If we traced out on the map of Europe the known remaining vestiges of these axes we should gain a very clear idea of the general plan of the whole. Thus, in Western Europe, the South of England corresponds to the Ardennes; the folds of Southern Brittany and Vendée widen out in the Central Plateau of France, then curve up south-eastwards so as partly to rejoin the Vosges and the Black Forest. True that the gaps are too great to permit of our following up with absolute certainty any given fold along the whole length of the Great Chain, but we are, at all events, in a position to determine the trend of an average or mean axis, which all the other axes doubtless follow at greater or less intervals.

The principle thus ascertained is of enormous value, however incomplete and shadowy it may appear at first sight. We may fairly say that it has revolutionized our methods of interpretation of the Palæozoic geology of Europe. And then—a point which concerns more nearly the matter with which we are dealing—it allows of a generalized comparison with the whole system of newer folds. These may be studied at those very localities where the Palæozoic folds are hidden beyond all chance of observation. Of course, such a study is no child's play. To begin with, as we all know, these folds are so slight that one would be almost entitled to assert that the word "fold" is improperly applied to such undulations of strata as those which, with few exceptions, hardly betray to the eye any divergence from the original horizontality. And then, from beneath the covering of vegetation and surface-soils, rock in place peeps out only here and there; finally, the general uniformity of the Chalk, for vast thicknesses, and the comparative scarcity of fossils, enable one only with great difficulty to recognize in it and follow up any definite horizons. All these obstacles,

however, have been overcome; a triumph for which we have largely to thank that indefatigable worker, the late Prof. Hébert. Moreover, it is just three years since M. Dollfus, of the French Geological Survey, embracing the question as a whole, published for the first time in a justly celebrated memoir a map on the 15 miles-to-the-inch scale ($\frac{1}{1000000}$) giving a general plan of the undulations of the Chalk in the Paris Basin.* Comparing this scheme of the newer undulations of the Paris Basin with that of the Palæozoic folds recognized outside its borders, we at once perceive that the Tertiary axes follow exactly the directions along which one would be disposed to join up the Palæozoic folds. Eastward, the axes sweep in curves which are concave towards the north, and which surround concentrically the similar curve of the coal-basins. This curve in its turn reproduces in an attenuated form the curve of the Palæozoic folds which southward surround the Central Plateau. Towards Brittany, the general westerly trend of the folds is not recognizable on M. Dollfus's map, because it has not yet been possible to trace out exactly the undulations in the Cretaceo-Jurassic region which borders the Western Palæozoic massif. In England, however, where the undulations of the Cretaceous and Tertiary strata have been studied with quite as much care as in France, their general strike is known to be east-and-west and parallel to that of the ancient folds of the coast. Everywhere, then, there is close interdependence betwixt older and newer folds—old and new, they all belong to one and the same tectonic system. The recognition of this fact, its application not only to one fold, but to a whole series of them, vastly increases the balance of probabilities in favour of Godwin-Austen's law.

If we wished to go farther, we should need to do in the case of each fold what Godwin-Austen was enabled to accomplish in the case of the North Downs, namely, follow it up to the Palæozoic boundary and prove that it is there in contact with and joins on to a fold of the older strata running in the same direction. Unfortunately, the demonstration is in most cases a matter of great difficulty. The Jurassic rocks which crop out at the junction with the Palæozoic swerve sharply westward, and thereby mask, as a rule, the effects of the folding. One exception, however, may be noted: the Merlerault Tertiary axis, one of the most considerable folds in the north of the Département de la Sarthe, has been recently shown by M. Lecornu to be an unmistakable prolongation of a Palæozoic axis.†

If we sum up what precedes, limiting ourselves to such points as are

* *Bull. des Serv. de la Carte Géol. de France*, July, 1890, No. 14, vol. ii.

† *Bull. Soc. Linn. de Norm.*, 1889, series 4, vol. ii.

beyond dispute, we find that (1) the system of Tertiary folds is arranged parallel to the main strike-lines (*lignes directrices*) of the older folds, following all their inflections; (2) in the case of the only two anticlinal folds which have as yet been traced up to the Palæozoic boundary, there is at the junction absolute coincidence, in position and in direction, with an anticlinal fold of the Primary rocks.

IV. THE BEARING OF MARINE DENUDATION ON THE QUESTION OF THE FOLDS.

Yet another series of arguments may be drawn from the study of ancient surfaces of marine denudation produced by the successive returns of the sea in Cretaceous and Tertiary times. This study in fact shows that there have been considerable movements, both in the comparatively short interval of time which separates the latest Jurassic deposits from the earliest Cretaceous, and in that which separates the latest Cretaceous from the earliest Tertiary. In some areas, at any rate, the movements produced in those intervals may be isolated from all others and studied quite independently: thus we find that though slight, the movements under consideration have given rise to true folds, and the axes thus formed coincide absolutely either with those of more recent folds, or with the axes which result from the superposition of all these movements.

The possibility of such a study is based on the fact that the sea in its gradual advance eats away the shore-line and planes down the old surface of the land, substituting, for the hills and valleys formed by older movements or carved out by atmospheric erosion, the practically horizontal surface of a plain of marine denudation. The new sea-bottom, if it could then be examined, would show almost a horizontal section of the older deposits; and a geological map of this sea-bottom would enable us to form a fair idea of the main features of the strata of which it is made up. The anticlinal folds would be marked by bands of outcrop of the more ancient rocks, or by noticeable indentations of their contours; conversely, the synclinal folds would be marked by bands of newer rocks; and lastly, supposing that the beds were not folded previous to marine denudation, but simply bent up in one mass towards some prominent massif corresponding to the ancient shore-line, the outcrops would occur in parallel bands whose contours would follow that shore-line in parallel order. If we wished to retrace such geological maps of the ancient sea-bed, it would evidently suffice to distinguish and to limit each of the surfaces along which the overlapping strata rest upon the various older rocks.*

* "Continuité du Phénomène de Plissement dans le Bassin de Paris," *Bull. Soc. Géol. France*, 1892, vol. xx., page 118.

V. THE FOLDS IN BOULONNAIS.

To take the district of Boulonnais as an instance, if we glance at the present geological map, we notice at once that the Lower Cretaceous (Wealden) rests indifferently upon all the Jurassic horizons, and that the Upper Portlandian is its immediately succeeding substratum in two small areas only, north and south of Boulogne respectively. The very insignificance of these areas proves how restricted was the outcrop of the Upper Portlandian on the Cretaceous sea-bed.

So too, in ascertaining the localities where the Cretaceous rests upon the Lower Portlandian, we see that the contour of the newer series enveloped that of the preceding series, repeating analogous sinuosities. Going thus backwards by successive series we find ourselves in a position to trace out the geological map of the bed of the ancient Cretaceous sea (Fig. 1, Plate IV.). The very form of the contours shows that their irregularities could not possibly correspond with old valley-bottoms; they point, therefore, to undulations of the sea-bed already existing when the sea returned, and thus afford evidence of pre-Cretaceous folding of the rocks.

If we are desirous of comparing these movements with those which the same surface has undergone since that epoch, we need only plot out (Fig. 2, Plate IV.) the contour-lines (*courbes de niveau*) of the base of the Cretaceous, as it now is. These contour-lines demonstrate, firstly, the existence of two median protuberances, one of which corresponds to the Palæozoic massif of Ferques, and the other to the site of the ancient Forest of Boulogne; but apart from this simultaneous movement (of which there was no sign before Cretaceous times), we notice that the contour-lines describe around the central dome a series of indentations and prominences which indicate that a set of parallel undulations ranged across the whole area. The axes of these post-Cretaceous undulations coincide with those previously observed in the case of the pre-Cretaceous undulations, and we therefore conclude that it is precisely on the site of the last-named that the later folds have been formed.

The verification of these facts in Boulonnais is especially important from the point of view of those who search for the continuation of the Coal-measure synclinals, for it is precisely around that area that we should look for these synclinals to be continued.

As to the foldings included between the Cretaceous and the Tertiary, the work of M. Cayeux has enabled the writer to complete an analogous verification in the Péronne-St. Quentin area, to the south of Arras (Fig. 3, Plate IV.).

The same method is applicable in the south and west of the Paris Basin, and in the west of the London Basin; and it leads to the same results. Armed thus with so many examples which confirm one another, we cannot possibly be taxed with reliance on mere fortuitous coincidences. During the whole duration of Secondary and Tertiary time, the crumplings of the surface in our part of the world have recurred again and again along the same lines.

VI.—THE FOLDS IN THE NORD COAL-BASIN (Plate V.).

The interest of the subject gains by extending a similar method of study to an area where Cretaceous overlie Palæozoic strata. The coal-basins of the North of France offer peculiar advantages in this respect, for there the underground workings necessarily connected with mining, make known to us both the appearance of the older rocks and that of the surface upon which rests the Cretaceous Series.

One might, however, question the applicability to the present case of the idea of a plain of marine denudation; and, indeed, the deposits which overlie the Palæozoic in this area are not everywhere exactly contemporaneous. Moreover, if we remembered that these strata are generally tough and long-resisting, we might expect that the ocean waves would hardly have succeeded in all places in breaking down the irregularities of the ancient land-surface, we might expect that some protuberant island-like masses would have withstood their efforts, and that some traces of old valleys would have been preserved. But, as a matter of fact, the contour-lines which have been recorded, betray no irregularities such as would remind us of the topographical relief due to the carving-tools of subærial denudation, and such as we should expect if marine denudation had been hindered in its differently destructive work. Then, too, in the case of old valleys, we ought to find fluviatile deposits at the base of the Cretaceous, or at least, we ought to find an increased thickness of basement-beds at these points. Such is the case in the Anzin "wash-out" (*torrent d'Anzin*), but that is, so far as known, an unique occurrence in this area.

As to the difference of age or non-contemporaneity of the basement-beds, the sole error thereby made possible is due to the movements which may have taken place between the various phases of denudation. If these were folding movements, then it matters little; for, as we have seen above, we have merely to deal with a superposition of movements along the same lines. If they were movements of a different nature, the part which they played can be determined just as easily if they preceded as if

they succeeded the process of marine denudation. The real problem that has to be solved is—the recognition, amid the inequalities of the contour-lines, of those which are due to folding. It is often difficult, sometimes impossible, to arrive at a perfectly certain solution; but the same difficulties await us in connexion with the topographic surface of any stratum whatsoever as with that of the Primary land. The important point, in both cases, is to have contour-lines which are exact, and fairly close to one another.

We are then justified in holding that the interpretation of the contour-lines of the surface of Primary rocks is likely to emphasize the existence of crumpling phenomena, and will allow of our comparing these more recent “puckerings” with the folds of the Coal-measures.

The contour-lines of the Primary land-surface were plotted out by M. Potier on the geological $\frac{1}{80000}$ or $1\frac{1}{4}$ inch map, at equal distances of 50 metres (164 feet). A glance at these contour-lines reveals at the two extremities of the French northern coal-field the exact coincidence of the younger depressions with the Coal-measure basin. North-east of Valenciennes, the crowding up together of the contour-lines points to a very deeply-hollowed basin, to which M. Olry gives the name of “Valley of Vicq;” the difference of level between the rim of that basin and the central hollow exceeds 500 feet. It can be followed in an easterly direction to beyond Mons, and coincides along its whole course with the Coal-measure basin. Moreover, south of this basin, another inflection of the contour-lines is noticeable around Quarouble: here the secondary basin is superposed on the small Coal-measure basin of Dour.

Westward, a very strongly-marked inflection of the contour-line (— 50 metres, that is, — 164 feet,) (Plate VI.) points to a similar synclinal undulation of the surface, situated exactly over the spot where the Coal-measure band thins away, between Bruay and Fléchinelle. But between these extreme points, the contour-lines, which are 164 feet apart, fail to demonstrate the existence of a series of parallel undulations: the Primary land-surface thus appears to be an irregular, hummocky, but not a folded area. Whence we can only conclude that the undulations, if they do exist, are too slight to be noticed in plotting-out contour-lines which are so far apart as 164 feet. The facts at our command are now sufficient to allow of drawing contour-lines only $32\frac{1}{2}$ feet apart; a glance at the map thus obtained then shows at once that the surface is folded. We notice first, in the central portion, a great line of depression (the Vicoigne fold) which is everywhere below the 262 feet level: it starts from the deep basin of Vicq, and runs south of the

Vicoigne mining property. In the Anzin mining property, relative depressions rarely exceed 65 feet, but three are arranged in a remarkable way parallel to the rim of the basin (Aniche fold, Denain fold, and Azincourt fold). The rim corresponds to a sort of "swelling" or bulging out, which follows it right along from the Belgian frontier to Douai. Lastly, farther south, though the available data are less numerous, we believe that another synclinal fold may be traced almost continuously: its presence was betrayed near Dour, as already observed, thanks to the contour-lines drawn by M. Potier. We have here, then, without taking into account the mining areas of Fresnes and Bruille, no less than five distinct synclinal folds which may be followed right across the map.

It now remains to be seen what is the relation between the position of these folds and the position of the folds of the older rocks. To begin with, the general trend is much the same as that of the Coal-measure basin, but the conformity goes deeper yet, and, deep as it goes, will still be found remarkably close.

Beginning with the north, the synclinal fold of Vicoigne occurs only in that mining property above the underground workings; and there a triplicate synclinal fold has been observed, the southern flanks of which are pushed abruptly upwards and even slightly turned over (Fig. 4, Plate IV.). The recent fold coincides in position and strike with the southernmost of these folds; above the two others is an area where it has hitherto been impossible to determine the contour-lines with sufficient precision to ensure trustworthy data.

The next fold, that of Aniche, occurs westward near Aniche, and eastward near Anzin, north of the Cran de Retour ("doubling-back") fault; somewhere between those two localities it runs south of that fault. If we consult the map of the different zones of the coal-field, published by M. Zeiller,* we notice that that contour follows almost exactly the boundary of zones B¹ and B² (lower and middle regions of the middle zone), restoring that part of the zone which is cut off by the Cran de Retour.

Now, in the Palæozoic rocks, there are signs of a synclinal fold corresponding to the north of the Cran de Retour. These may be observed in the workings of the Thiers pit and the St. Louis pit (mining property of Raismes). Farther westward, the fold, if it be continued, is thrown deeper by the Cran de Retour, but reappears, well-marked and easily recognizable, in the workings of the Douai and Escarpelle area. Besides affecting the same group of beds as elsewhere, it coincides in that

* *Bassin houiller de Valenciennes. Description de la Flore Fossile*, page 692, Fig. 46.

area with the Tertiary fold. It is fair, then, to say that the coincidence is interrupted by the fault only, that fault not having moved or worked back at the same time as the folds.

The next two folds, that of Denain and that of Azincourt, correspond to the southern part of the basin. It would be useless to attempt to seek a precise coincidence with one or other of the numerous folds of this portion of the coal-basin, the more so that the Azincourt fold can only be traced with certainty in the mining property of that name, where it remains outside the limits of the basin. The last mentioned circumstance is perhaps explicable if we consider that the older fold is there turned over (*couché*), and Devonian and Carboniferous strata overlie the centre of the coal-basin. All we can look for is a general coincidence, and so much is an undeniable fact. The Denain and Azincourt folds correspond in strike with the zone B³ of M. Zeiller (upper division of the middle zone).

It is noticeable that the Aniche and Denain folds cross, and follow the middle portion of, the wash-out (*torrent*) of Anzin. The sands to which this name has been given date, as we know, from the Lower Cretaceous; they are probably fluvial, and are in any case anterior to the period of the final return of the Cretaceous sea to that region. That these sands were more likely laid down, and more easily preserved, in a synclinal depression seems sufficiently obvious.

Lastly, as to the fifth fold, that of Dour, its coincidence on the west side with the little Secondary basin of the same name has already been noted in these pages. Towards Douai it unites, outside the limits of the coal-basin, with the western branch of the deep depression of Douai.

The result of the foregoing considerations tends then to show that there is a coincidence between ancient folds and recent folds; that this coincidence appears to extend to minute details, and to exceed in precision all that one might have expected from phenomena, which, owing to the complex nature of the resistances that come into play at every point, can hardly be adjusted to geometrical laws. The confirmation of our principle is so convincing as to admit of no doubt.

The accompanying section (Fig. 4, Plate IV.) enables us to compare the features of the strata which are now being worked for coal, with those of the land-surface of Primary rocks (the heights of which are exaggerated thirty times). The section shows that repetition of folds along the same lines does not result in the formation of similar surface-reliefs, where the newer system of folds reproduces on a smaller scale the older one. One reason is that there is no proportionality in the relative accentuation of the

various folds which are superposed one upon the other. Moreover, the Vicoigne depression has all the look of belonging to another order of phenomena; it is in fact the rim of the Vicq depression, where a local subsidence is superposed on folding, and where four out of our five folds unite and merge into one another. We conclude then, that, over a considerable area, the general inclination of the more recent strata is the reverse of the inclination of the older beds, wherefore there is absolute divergence between the two profiles. The influence of the folding action is none the less marked in the general trend of the contour-lines, and this is chiefly owing to the parallelism of the undulations.

VII. THE FOLDS IN THE PAS-DE-CALAIS COAL-BASIN. (Plate VI.).

It would be interesting to study from a similar standpoint the Pas-de-Calais area. Meanwhile, by the mere inspection of the curves plotted out by M. Potier, some not unimportant conclusions as to the geology of the coal-field may be arrived at. Even on small-scale maps (of France, say, at the $\frac{1}{1000000}$, or 15 miles to the inch) it will be seen that the northern rim of the coal-basin shows numerous sinuosities, as for example near St. Amand, Anneulin, and Béthune. The localities where the Carboniferous Limestone thus protrudes into the coal-field evidently denote remnants of anticlinal folds of the older strata—at least, such is the case if we admit that the Primary land surface (or surface of erosion) was formerly horizontal; conversely, the areas where the Coal-measures form promontories projecting into a mass of older strata, correspond to synclinal folds. Now, in the Département du Nord, as will be seen by the map (Plate V.), the synclinal fold which occurs north of Vicoigne, in other words, the fold of Vieux Condé (to which the writer has not hitherto referred) terminates near St. Amand, issuing from the coal-basin precisely on the site of one of these synclinals. Similarly, the northernmost of the two folds which was mentioned as corresponding to the Vicoigne fold, issues from the coal-basin near Marchiennes, in the second of these synclinal creeks. The track (so far as yet known) of the southernmost of these two folds, if continued into the Pas-de-Calais, leads one to infer that after passing by Ostricourt it issues from the basin at Anneulin, while the Aniche fold issues therefrom south of Béthune.

Here, again, then, we have a series of coincidences, the importance of which can hardly be overlooked. And from the point of view of the tectonic structure of the coal-basin an instructive conclusion may be drawn, viz., that this basin does not correspond to a single fold, but to a set of folds, slightly oblique to the mean strike of the coal-bearing

band, a conclusion which throws a new light on the overlap of the coal-bearing strata, and to which M. Potier long ago drew attention.*

In fact, if we combine the foregoing data with the results attained by M. Zeiller's map, we shall see that the Vieux-Condé fold, or rather the anticlinal fold which limits it to the south, practically corresponds with the boundary of the anthracitic group (A^1 of Zeiller); the Vicoigne fold with that of the Nord close-burning coal group (A^2); while the Aniche fold, which may be regarded also as that of Béthune, corresponds (as already remarked), with the boundary of the zones B^1 and B^2 . In other words, the very folds with which we have been previously dealing, foreshadowed or dimly outlined before the Coal-measure upheaval, have successively checked the progressive southward advance of the Coal-measure lagoons. Wherefore, if at a given locality we know by fossil evidence the age of the Coal-measure horizon which rests upon the Carboniferous Limestone, or at any rate upon the latest unquestionably marine strata, we may, to some extent and with some chance of probability, conclude which is the fold upon whose prolongation that locality is situated.

The information would be valuable, for instance, in the case of the district of Boulonnais, but unfortunately no precise data have as yet been obtained from the coal-flora of that area. It may be as well to add, however, that in no case could such a conclusion be accepted unreservedly, because a fold which constitutes a shore-line along part of its course does not necessarily continue so along its whole course. But one conclusion we may at all events bear in mind, and that is, that over the North of France coal-field, the recent folds are, as it were, moulded upon the older folds.

VIII. SUMMARY OF CONCLUSIONS DRAWN FROM THE EVIDENCE IN THE NORTH OF FRANCE.

To sum up, the arguments which may be invoked in favour of Godwin-Austen's principle are the following:—General concordance in the "scheme" of the Palæozoic folds and that of the recent folds. Exact superposition in the various phases of the later folding. Unbroken junction at their common extremities of several folds belonging to both series (*e.g.*, Mendip Hills and Merlerault). Complete and continuous coincidence of both series above the coal-basin of the Département du Nord.

One may be inclined to generalize from these results, or the reverse; one may seek to reserve the possibility, at any rate, of important exceptions to the rule; but there is now no doubt that, so far as the North of France and the South of England are concerned, the observer may be guided by

* *Assoc. Franç. p. l'Av. des Sciences*, 3^{ème} session, Lille, 1884.

the undulations of more recent strata in looking for the axes of the Palæozoic folds. It is no less certain that in a search of that kind the observer may take as a basis the contour-lines of the surface of any particular bed in the series or of any surface whatsoever of ancient marine denudation. It should be borne in mind, however, that the rule necessarily loses much of its precision in those cases where the ancient folds are "dissymmetric" or overfolded, because a single line drawn along the surface is hardly sufficient to define the site of an "overfold" (*pli couché*).

IX. APPLICATION OF THE PRINCIPLE TO THE COAL-BASINS OF THE PAS-DE-CALAIS, THE BOULONNAIS, AND DOVER.

The first problem which demands solution is to join up the known folds (near the extremity of the Pas-de-Calais coal-basin) and those which have been already determined for Boulonnais. The data available in the intervening area unfortunately are so far inadequate. We can only make use (Plate VI.) of the contour-lines of the surface of Primary rocks, plotted out by M. Potier in his detailed geographical map, and farther westward the contour-lines of the base of the Chalk-with-*Micraster-breviporus*, obtained from a recent work by M. Parent.*

In examining the surface of the ancient rocks one is struck by the island-like protuberances which run higher than the 164 feet contour. Southward runs the long saddle [ridge] of Fauquembergue and Vimy, with the subsidiary promontory which juts out westward of Fruges towards Hucqueliers; farther north lies the little prominence of Rébergues (where the Devonian crops out), and lastly, the massif of Ferques, north of Boulonnais. Putting aside for a moment the protuberance of Hucqueliers, it seems natural to assume that the line of Ferques-Rébergues-Fauquembergue represents, despite some depressions along its course, an anticlinal axis, northward of which the continuation of the Coal-measure synclinal should be sought. Such was the solution favoured by Godwin-Austen and recently maintained by Dollfus.† But the writer firmly believes that an attentive study of the contour-lines will entail its immediate rejection. To begin with, this line does not present everywhere the same characteristics. True, that from Ferques to Rébergues, the Primary land-surface sinks on either side of the line; and the same statement holds good east of Fauquembergue, but in the intervening space the conditions are different. The base of the Cretaceous, which, from Flanders onwards, rises continuously towards that line, continues to rise on the other side

* *Annales Soc. Géol. Nord*, vol. xx., page 304.

† *Bull. des Serv. Carte Géol. France*, vol. ii., No. 14, page 49.

of it towards the centre of Boulonnais. The line, for a distance of 12 miles, ceases to mark the separation between two declivities—it loses the character of an anticlinal axis. On the other hand, there is a well-marked anticlinal axis south of St. Omer, which runs thence a little above Lumbres. Lower down a parallel synclinal fold is equally well-marked between Aire and Remilly. These two folds are oblique to the Rébergues-Fauquembergue line, and denote the true direction of the whole system. We may add, as was long ago observed by M. Gosselet, that the Artois axis (or axis of Condros) has everywhere to the east formed the northern shore-line of the Lower Devonian sea. The absence at Ferques of rocks of that age being amply proved, the inference is obvious that this locality lies north of the prolongation of the fold. And thus we are supplied with yet another argument for concluding that the Artois axis does not run up to the north of Boulonnais.

Another solution which appears to offer itself quite naturally is the joining up of the Pas-de-Calais coal-basin (Auchy-au-Bois and Fléchinelle) with that of Boulonnais. As a help to this solution we may recall the existence of a great overturned fold south of both coal-basins. M. Breton* objects, on the score of the difference of composition of the Coal-measures in the Pas-de-Calais and Boulonnais respectively. The contour-lines offer no obstacle to the solution, but they indicate as more probable the correspondence of the Hardingham "system" with the Secondary synclinal of Béthune.

Lastly, M. Parent has shown that the depression which limits Boulonnais southward, between Neufchatel and Ergny, was prolonged north-eastward towards Delette by a less strongly-marked depression, and appeared thus to join up with the Fléchinelle synclinal. But an attentive study of the contour-lines shows that in reality the depression bifurcates, and the branch which runs down towards Fruges alone corresponds to the general scheme of the system of folds. Perhaps the diverging ramification of Delette is neither more nor less than the tag (*amorce*) of a circumferential depression around the central dome of the Forest of Boulogne. Neither, therefore, does the Artois axis run south of Boulonnais.

Its continuation should at all events be looked for within Boulonnais itself, but the insufficiency of the data at present available only enables us to infer its termination north or south of Wimille. The Fléchinelle synclinal axis would then on one hypothesis debouch at Cape Gris Nez, on the other near Wimille. The writer may add that, independently, five anticlinal and synclinal folds have been determined near Béthune, and five similar folds in Boulonnais; further, that the junction of

* *Ann. Soc. Géol. du Nord*, vol. xix., page 24.

the extreme folds of the double series has been ascertained, and that consequently there is a great balance of probability in favour of the junction pair by pair of the intermediate folds. Thus the axis of Artois is correlated with the fold of La Crèche, so well marked in the Jurassic cliffs north of Boulogne.*

X. THE EVIDENCE FROM BORINGS.

Comparatively few borings have been made in central and southern Boulonnais. M. Rigaux, in his very complete memoir on that district† says, with due reservation, that old borings are supposed to have struck the Silurian rocks at Mont des Boucards and Le Wast. MM. du Souich and Delanoue refer to the Silurian shales which have been met with in a boring at Lottinghen. These somewhat doubtful results would, if confirmed, indicate the existence of an old anticlinal below the recent anticlinal of the upper valley of the Liane.

Borings between Rébergues and Escœuilles have struck the Carboniferous Limestone, limited north and south by the Devonian; therefore, the old synclinal of Hardingham passes just at the spot whither we have traced the newer synclinal. Two borings, at Moulin-des-Moines and Basse Falaise, south of Hardingham, have struck, one the Carboniferous Limestone below 790 feet of Devonian slates, the other Coal-measure shales (82 feet only) below 633 feet of Carboniferous Limestone and 265 feet of Devonian slates. The prolongation southward of the overturned fold serves to explain why the recent synclinal is there carried some distance south of the outcrop of the older synclinal.

Unfortunately, however, farther south, just where information would be most interesting, very few borings have been made. That of Desvres, at 768 feet, struck clay-slates, on the age of which M. Rigaux offers no opinion, while M. Gosselet is tempted to refer them to the Lower Coal-measures. A more recent boring, the exact results of which are unknown to the writer, seems to have confirmed that supposition, and it would in fact agree with the known existence of a recent synclinal at Desvres.

Lastly, a boring has been carried on at Boulogne itself at the factory of Montataire. The boring was at first stopped at 777 feet in a very tough Oolitic limestone, regarded as Carboniferous Limestone. Thereafter the boring was deepened by 197 feet, the whole thickness of which consisted

* Since the paper was written M. Parent has sent the writer some new observations which modify the geological information and maps upon which this conclusion was based. The writer is now induced to admit that the Artois axis passes to the south of Boulonnais. Practically, however, this does not affect the other conclusions of this paper.

† *Notice Géol. sur le Bas Boulonnais, Mém. Soc. de Boulogne, 1892.*

white sands and lignite-bearing clays: these represent, beyond any possibility of doubt, the base of the Jurassics of that district. So that the Eolitic limestone, erroneously attributed to the Carboniferous, is really Bathonian [Great Oolite]. The boring was not continued beyond 981 feet, and though at that depth it had not yet struck the Palæozoic rocks, it must have been close upon them.

XI. APPLICATION OF THE PRECEDING CONSIDERATIONS TO THE DOVER BASIN.

From the foregoing considerations we are enabled to conclude that the Pas-de-Calais coal-basin, whether or not ramifying into two distinct branches in Boulonnais, does not debouch on the coast anywhere north of Cape Gris Nez. The anticlinal fold which forms the northern boundary of Boulonnais corresponds to that which, near Folkestone, forms the northern boundary of the Weald. We are therefore led to the further conclusion that the newly-discovered coal-basin of Dover is distinct from the Pas-de-Calais coal-basin.

In looking for the prolongation of the Dover coal-basin we notice that the contour-lines of the base of the Glauconitic Chalk [Chloritic Marl] indicate near the coast the existence of a series of undulations sensibly parallel to the shore-line. These undulations are moreover parallel to those which furrow the neighbouring sea-bed of the North Sea and the Straits of Dover. Clearly, they make up a system which is transverse and practically perpendicular to the system of principal folds which run across the Straits, and therefore they provide us only with indirect guidance as to the axes that we ought to follow up.

But this does not hold good of the contour-lines carried along beneath the Straits by MM. Potier and de Lapparent. These give evidence of a sudden drop of the strata northwards, which is sufficient to mark, if not the exact position, at all events the average direction, of the fold which starts at Folkestone. Bearing in mind that this sudden drop of the strata is paralleled by the rapid downward plunge of the Aptian Beds [Lower Greensand, and Atherfield Clay-beds], observed on the French coast near Wissant, we are enabled to plot out approximately the actual axis of the fold, whereby we gain the conviction that it ultimately joins up with the saddle of Ferques. And the line thus traced is found to be very nearly perpendicular to the great furrows of the sea-bed.

We are acquainted, moreover, with a small Secondary saddle on the Kentish coast between the Folkestone fold and the Dover coal-basin. The submarine outcrops here also enable us to follow for several miles the

axis of this Secondary fold which bends rapidly eastward and even north-eastward. So we have one more valuable junction-tag.

If we wish to follow still farther these tags or remnants, our one remaining resource is to study the contour-lines of the present sea-bed. This bed, like that of the ancient seas, is a surface of marine denudation, and the same conclusions are here applicable as there. True, that in the case of our recent seas the objections urged in another portion of this paper seem to acquire additional strength. In the North Sea the accumulation of glacial detritus, and in the Straits of Dover the part played by the sea-currents appear amply sufficient to vitiate our conclusions; and yet, despite the intervention of causes of error so undeniable, the general scheme of the folds has not been obliterated. The contour-lines, both in the North Sea and the English Channel,* make strikingly manifest a double system of rectangular furrows, which join up with the folds already known on either shore. We make, therefore, no very rash assumption if we presume that the study of these contour-lines will in this particular case provide us with some useful data. No doubt the indications thus obtained will be merely approximate; because, for one thing, the transverse furrows alone are well marked in the Straits, and for another, the sinuosities of the contour-lines around these furrows are both too minute and too numerous to allow of our plotting-out the second system with anything like precision. In point of fact, for the purposes of that scheme, we are led to rely on the condition of perpendicularity (of one system to the other), and this is, and can only be, a matter of approximation. The only well-known fold on the English coast, besides those mentioned above, is the Thanet axis,† of which one might, perhaps, place the termination at Ostend (where boring has proved the Silurians at 984 feet); the Hougham Fold, starting immediately south of Dover, terminates near Calais (Fig. 5, Plate IV.).

It is therefore between those two points that we ought to look for the continuation of the Dover coal-basin. Whether intermediate undulations occur between the Isle of Thanet and Dover is unknown; nor do we know whether Dover is near to or far from the axis of the Coal-measure synclinal. All that we can say, as the result of the application of our method, is that the homologous point of Dover would in France lie a little east of Calais. If the Dover coal-basin does reach into France, its continuation must therefore be sought east of Calais, between that town and Dunkirk.

* *Bull. Soc. Géol. France*, vol. xx., page 156.

† M. Barrois considers that the Thanet axis is a transverse fold; but I am unable to agree with him herein, for it appears to me that the Thanet axis is evidently continued by the outcrops of Chalk mapped along the Thames.

The writer would add one remark which seems to him important from the theoretical point of view: if the folds of the Nord, as he has said, run slightly oblique to the Coal-measure band and debouch in the successive creeks of the rim of the coal-basin, it becomes highly probable that it is the Vicoigne fold that has been met with at Dover. Whence we would infer that the coal-basin of the Nord branches out westward into a series of ramifications, some of which, at all events, only intermittently cease from being productive.

It is known that a boring was formerly undertaken at Calais, but unfortunately the results are doubtful and much disputed. The boring was stopped at a depth of about 1,150 feet, after having below the Greensands passed through about 35 feet of a foetid, sub-Oolitic limestone, regarded by some as Palæozoic. M. Laurent, who directed the boring operations, hints at Coal-measures, an assertion which seems hardly tenable. Élie de Beaumont, who saw the specimens brought from the bottom, assigned them to the Carboniferous Limestone, and that appears the most likely view. On the other hand, the oolitic character of the rock has led observers to suppose that here, as at the Montataire factory, Jurassic limestone had possibly been confounded with Carboniferous. The specimens which passed through the hands of Élie de Beaumont have not been traced, in spite of the search made by M. Potier, and there is reason to fear that this doubtful point will never be settled, unless a new boring be made.*

The writer has already mentioned the Ostend boring, which proved at 984 feet the Silurians immediately below Tertiary strata. Three other borings (near Guines and St. Omer) have also proved very ancient rocks, probably Devonian and Silurian. None of these data, however, help to solve the problem.

XII.—GENERAL CONCLUSIONS.

The object of this memoir, a purely geological piece of work, is not and could not be, the prediction of the occurrence of Coal-measures at such and such a spot. The method we have adopted simply enables us to follow at the surface the axes of known coal-basins. But we should also require to know whether Coal-measures, in the area we have studied, were laid down along the whole extent of these basins. The westward overlap of the different divisions of the Coal-measure series shows that the shore-line of the Coal-measure lagoons lay to the west, and the occurrence of coal at Hardingham leads us to infer that this shore-line was situated

* The Calais boring is tubed, and may be deepened at any time.

... the *vicinities of northern France and Southern England.*

REFERENCES.

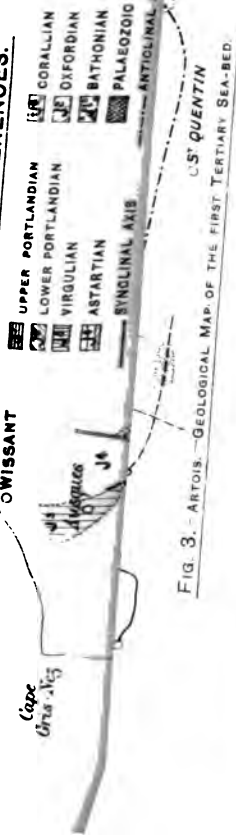


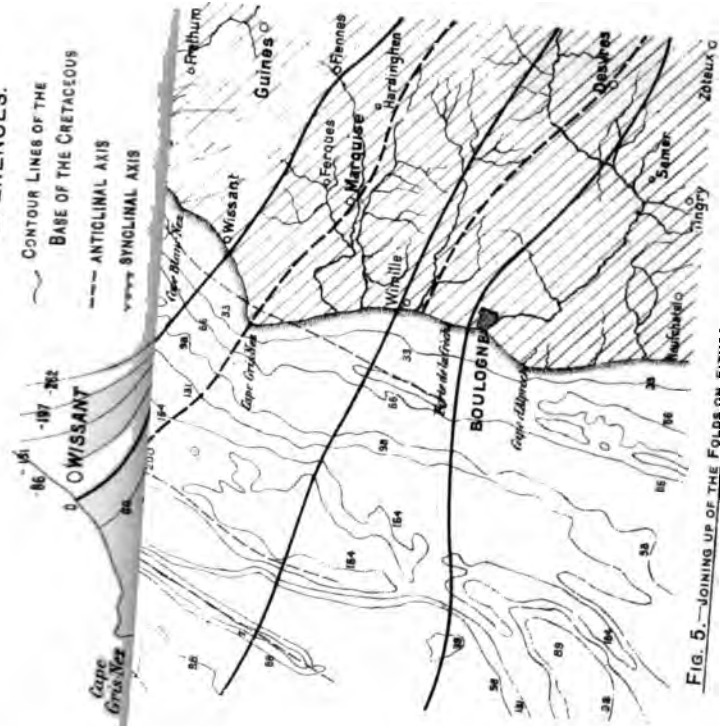
FIG. 4.—COMPARATIVE SECTIONS OF THE COAL MEASURE BASIN (HEIGHTS TO SCALE) AND THE SURFACE OF THE PRIMARY STRATA (HEIGHTS MAGNIFIED 30 TIMES).

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And "Raid Souda" of Lybae Westside

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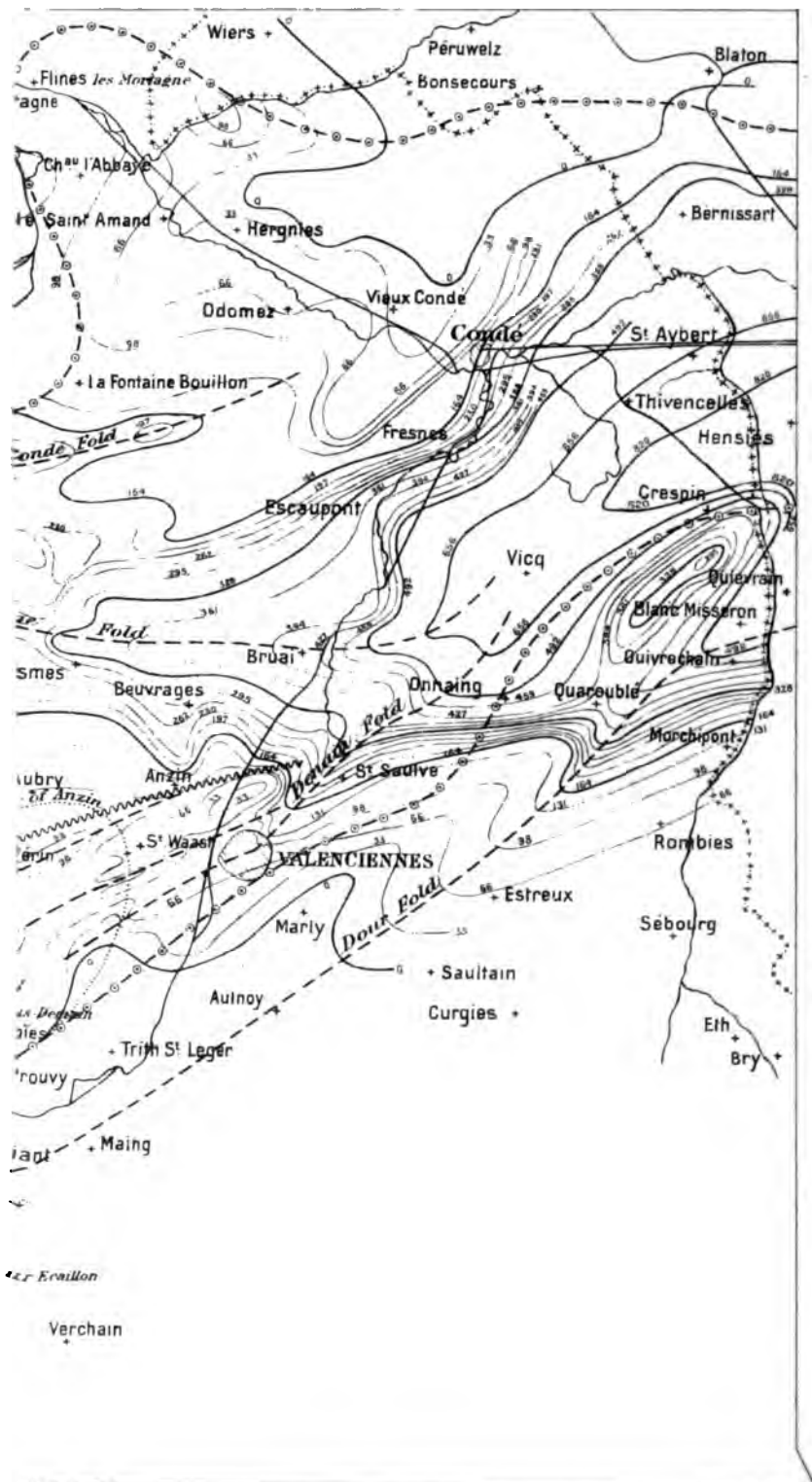


FIG. 7.
MAP OF THE CRETACEOUS AND TERTIARY UNDULATIONS
IN THE
PAS-DE-CALAIS.

REFERENCES.

- | | |
|--|---|
| — CONTOUR LINES OF THE SURFACE OF
PRIMARY ROCKS, INTERVALS OF
164 FEET. | --- CONTOUR LINES OF THE BASE OF
THE CRETACEOUS (WEALDEN)
INTERVALS OF 66 FEET. |
| ■ ANCIENT ROCKS ABOVE 164 FEET. | - - - SYNCLINAL AXIS. |
| --- CONTOUR LINES OF THE BASE OF THE
CHALK WITH <i>Micraster breviporus</i> . | — ANTICLINAL AXIS. |
| | ▨ COAL BASIN (TOURTIA OUTCROP). |

Scale - 320,000

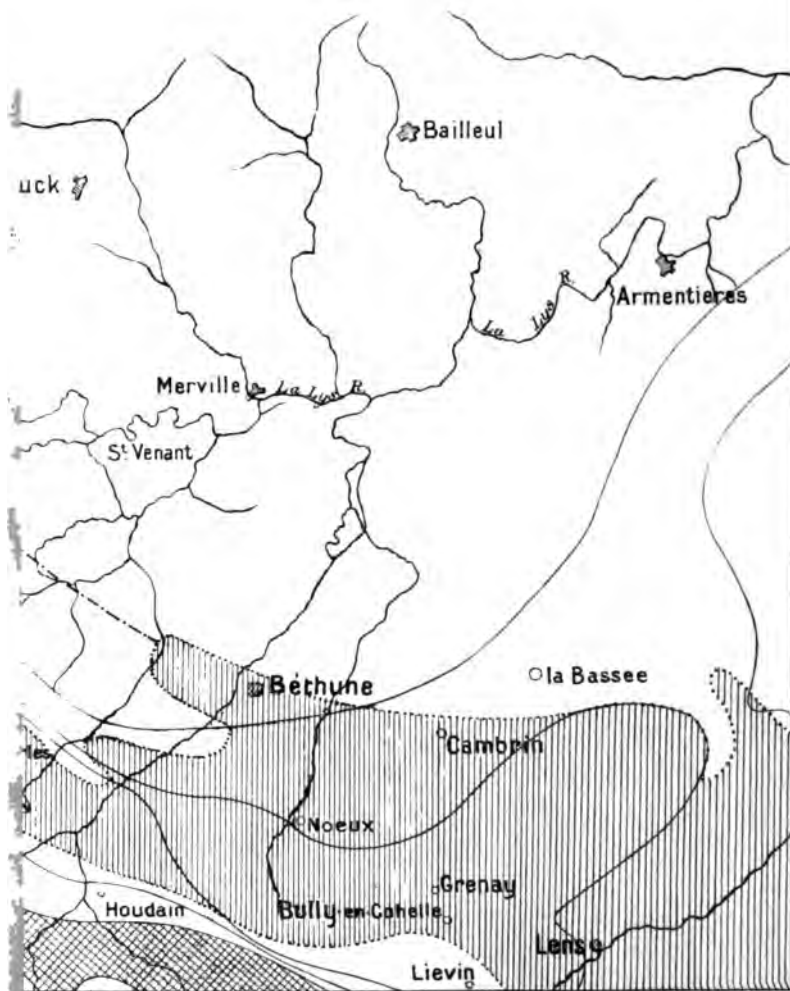


FIG. 7.

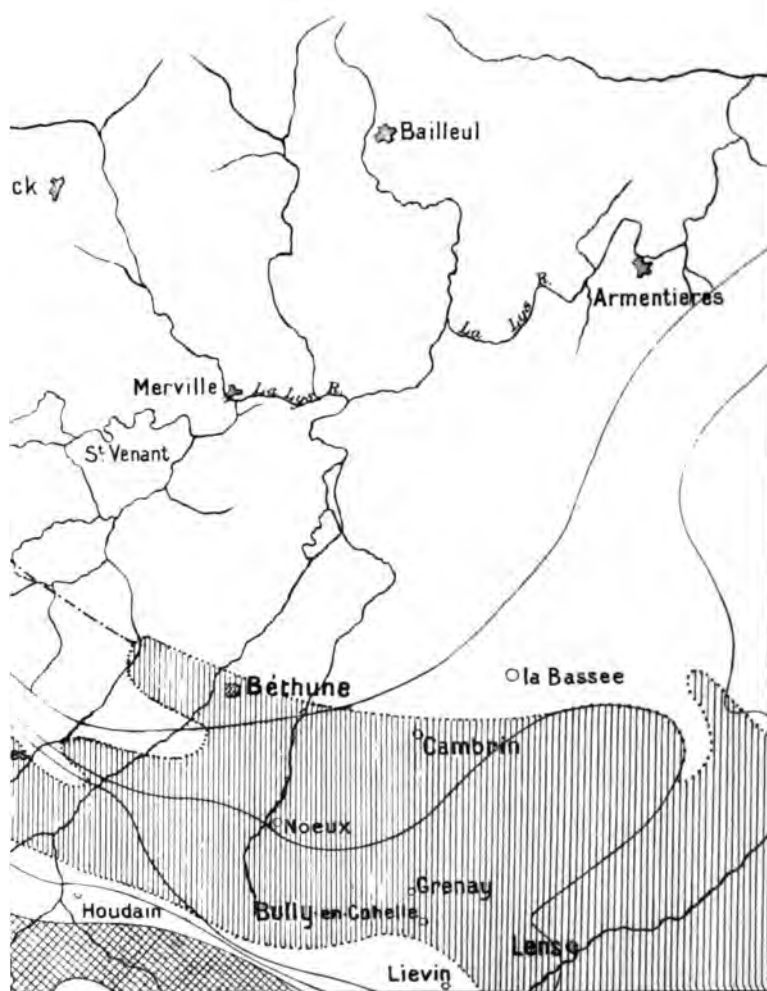
MAP OF THE CRETACEOUS AND TERTIARY UNDULATIONS

IN THE
PAS-DE-CALAIS.

REFERENCES.

- | | |
|--|---|
| — CONTOUR LINES OF THE SURFACE OF
PRIMARY ROCKS, INTERVALS OF
164 FEET. | ----- CONTOUR LINES OF THE BASE OF
THE CRETACEOUS (WEALDEN)
INTERVALS OF 86 FEET. |
| ■ ANCIENT ROCKS ABOVE 164 FEET. | --- SYNCLINAL AXIS. |
| CONTOUR LINES OF THE BASE OF THE
CHALK WITH <i>Micraster breviporus</i> . | — ANTICLINAL AXIS. |
| | ▨ COAL BASIN (TOURNAI OUTCROP). |

Scale - 320,000





beyond the area of Boulonnais. So much is very probable. But the mere occurrence of Coal-measures, granted that it be proved, does not necessarily imply the occurrence of coal.

We should further require to know at what points of the basin coal-measures have been preserved, and at what points they have been eroded away; and that we cannot possibly predict. All we could say would be that there are considerable chances that the basin is deeper where it is crossed by great transverse depressions. The Straits of Dover are unquestionably one of these transverse depressions, and one of very ancient origin. Yet the data at our disposal on this point do not carry us back beyond the Jurassic period. Very likely the coal had a better chance of being preserved along the edges of this depression, but the statement amounts purely to a supposition.

The conclusions which, to the best of the writer's belief, sum up the state of our knowledge on this question, and which, at any rate, lay down the bases of all possible discussion, are as follows:—

The undulations of Secondary and Tertiary time have always recurred along the same lines, and not only do these lines follow the general direction and even the principal inflections of the Palæozoic folds, but also (wherever study of the evidence has been possible) are proved to coincide exactly with the axes of those folds. This is borne out in the coal-field of the Nord with an exactness which extends to minute details.

Our principle enables us to trace out the ancient folds by the mere study of the surface-rocks; the application of the method is attended with some difficulty, partly on account of the slowness of the undulations which are the object of our search, partly because of the local upheavals and subsidences which mark the original folding.

We may, however, affirm that the Dover coal-basin is distinct from that of the Pas-de-Calais, and that the axis of Northern Boulonnais (saddle of Ferques) is not the prolongation of the axis of Artois. Two directions are fairly presumable for the continuation of the Lens-Théchinelle basin: one abuts a little north of Boulogne, near Wimille; the other, keeping more to the northward, merges in the little coal-basin of Hardingham, which, on the first hypothesis, would only be a branch of the principal basin.

The prolongation of the axis of the Dover basin lies hidden beneath the waves; and, judging from an inspection of the isobathymetrical lines (curves of equal depth) this axis debouches on the French coast, a little to the eastward of Calais.

Mr. LUDOVIC BRETON (managing engineer of the works of the Submarine Railway between England and France) stated his belief that the Dover coal-basin was independent of the other English coal-basins, and independent also of the French. In England there was a tendency to connect it with the Somerset coal-field, but he must point out that of the eleven fossil plants hitherto found in the Dover boring and determined by Mr. Zeiller,* four only are common to the coal-basins of Somerset and Dover. These are : *Neuropteris Scheuchzeri*, *N. rarinervis*, *Lepidodendron aculeatum*, and *Stigmaria ficoides*, but as the two last-named plants occur in Coal-measures everywhere, they cannot be used as terms of comparison. As to the other carbonaceous impressions of plants from Dover, *Neuropteris tenuifolia*, *Maryopteris sphenopteroides*, *Lepidostrobus variabilis*, *Calamophyllites Gæpperti*, *Cyclopteris*, *Lepidodendron lycopodioides*, and *Cardiocarpus*, they are so far unknown in the Somersetshire coal-field. Nor does the Dover coal-basin resemble, in its flora, that of Lower Boulonnais : of the eleven fossil plants found at Dover, three only are found to recur in Lower Boulonnais. They are the inevitable two *Lepidodendron aculeatum* and *Stigmaria ficoides*, the third being *Lepidodendron lycopodioides*. The different kinds of rocks occur in very dissimilar proportions in the two basins thus :—

	Coal. Per Cent.		Sandstone. Per Cent.		Shales. Per Cent.
Dover boring	2.20	...	55.60	...	42.20
Providence pit, Hardingen	5.86	...	14.00	...	80.14

Fig. 8 is the vertical section of the Dover boring, and Fig. 9 that of the Providence pit, at Hardingen. The observer is supposed to be stationed in England, having the Dover boring on his left, and on his right the Providence pit, of Hardingen, with its coal-seams dipping 18 degs. to 20 degs. north, and the fault which separates the Coal-measures from the overlying Carboniferous Limestone dipping 11 degs. north. The analyses which have been made at the National School of Mines in Paris show the following results for Hardingen coal :—

Volatile matter	35.4 to 38.6 per cent.
Fixed carbon	61.8 „ 57.8 „
Ash	2.8 „ 3.6 „
	100.0 100.0

This is what in France is termed a “long-flame dry coal.” It is of more recent formation than the Dover coal, where the highest seams yield no

* *Trans. Manchester Geol. Soc.*, vol. xxii., page 55.

coal containing more than 25 per cent. of volatile matter. In a paper on the Carboniferous formation of Lower Boulonnais, he (Mr. Breton) had given his reasons for not believing that the Hardingen coal-basin dates from the same period as the Pas-de-Calais coal-basin. He was just as incredulous with regard to the correlation of the Dover coal-basin with that of the Pas-de-Calais. Let us take, for instance, a centrally-situated mining property, that of Bully-Grenay, where the study of Coal-measure fossils has been most diligently pursued. There, of 80 fossil plants described by Abbé Boulay, two only are common to the Dover boring: they are *Stigmaria ficoides*, found everywhere in the roof and floor of the seams, and *Lepidodendron aculeatum*. Thus 78 fossil species are not found at Dover, a dissimilarity of flora which seemed to the speaker hardly capable of being exceeded. Of course, it was true that a careful search throughout the entire range of coal-fields of the Pas-de-Calais, the Nord, and Belgium, would reveal the occurrence of representatives of the Dover coal-flora; but one plant would be found at Marles, another at Bruay, a third at Nœux, and so on. That is not, however, the sort of occurrence sufficient to bring conviction to

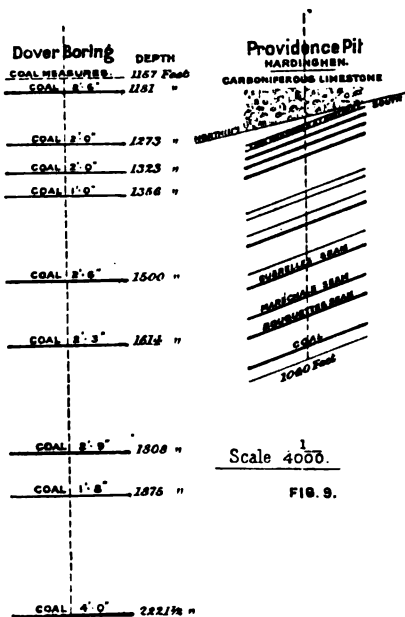


FIG. 8.

the mind of anyone who believes that fossil-plants constitute a highly important factor in the correlation of two coal-basins. And now, how and where does the Dover coal-basin pass into France? Nobody will deny that it does extend thither. But it is not at Guines, where two borings have struck Devonian rocks; and the hypothesis of a geological disturbance, like that which limits to the south the Coal-measure zone of the Pas-de-Calais, would be the only way of accounting for Coal-measures being overlain by more ancient rocks. If the limestone found at the bottom of the Calais boring be Carboniferous, we should have to invoke the same reasons as at Guines to allow of the Dover coal-basin continuing across to Calais; that is, a repetition of geological

disturbances affecting the Hardingham coal-basin, which itself lies below Carboniferous Limestone, except at the eastern outcrop. In his summary of conclusions, Mr. Marcel Bertrand says that probably the axis of the Dover coal-basin debouches on the French coast, a little to the eastward of Calais. This question will have to be settled by means of the borings, which will, no doubt, shortly be undertaken. It would be seen that in France they hastened slowly, when one remembered that coal was struck at Dover on February 15th, 1890.

Mr. E. REUMAUX (Lens) wrote that Mr. Bertrand's conclusions were not yet supported by a sufficient number of well-established facts, but his work was of an entirely original character, and he enunciated, with new arguments, a system which may well be received at some future date.

Prof. GOSSELET (Lille) wrote that Mr. Bertrand's paper was well worthy of careful consideration. He agreed with him as to the continuity of the phenomena of the folds of the earth's crust, which he demonstrated so clearly. But he (Prof. Gosselet) was less convinced of the absolute exactitude of Godwin-Austen's principle, which did not appear to him to be proved, that the undulations, synclinals and anticlinals, affecting the Secondary and Tertiary rocks are always superposed exactly over the folds of the Palæozoic rocks. As to the connexion of the Dover coal-basin with that of the Nord (Valenciennes and Pas-de-Calais), he (Prof. Gosselet) did not accept Mr. Bertrand's views in their entirety. Two suppositions appeared possible:—(a) The Dover coal might belong to a basin similar to that of Warwickshire and Worcestershire, lying unconformably upon the extension of the Silurian schists found at Caffiers and Ostend: (b) the coal at Dover might be an extension of the Pas-de-Calais coal-field, whose western extension might be found near Bristol and in South Wales. He (Prof. Gosselet) preferred the second of these theories, without deciding that the first was impossible. This basin underwent, between Boulonnais and Dover, a cast to the north, similar to that which it experiences near Douai. He (Prof. Gosselet) considered that the Hardingham (Boulonnais) coal did not occur (as Mr. Bertrand thought) in a different synclinal trough from that of the great Valenciennes, etc., coal-field; but that it was a portion of the same coal-field thrown northward by a series of very oblique faults.

Mr. G. C. GREENWELL (Derby) wrote with respect to the horizontality of the strata bored through at Dover, that he had examined a specimen of the core, where passing through blue shale (now exhibited in the Natural History Museum), which did not seem to show horizontality of the beds. There are sufficient boring-tool-marks to show the vertical axis of the

specimen, but the flat leaves of *Neuropteris* indicated that the plane of the stratum was inclined at an angle of at least 45 degs. from the horizontal.

Mr. T. V. HOLMES (Greenwich) wrote that, while recognizing with Mr. Bertrand a strong tendency to the recurrence of geological folds along the same general lines, it seemed to him that to say that "the principle from which Godwin-Austen proceeded is summed up in the axiom that recent folds are formed along the same lines as ancient folds," is decidedly to over-estimate his belief in their identity. Godwin-Austen pointed out that the Palæozoic ridge of the Mendip Hills was in all probability continuous (beneath the Secondary and Tertiary rocks of South-eastern England) with the Palæozoic ridge south of the coal-fields of Namur and Charleroi, and that, alike in Belgium and in Somerset, the coal-fields were north of the Palæozoic ridge. But he contented himself, as regarded South-eastern England, with saying that "we have strong *à priori* reasons for supposing that the course of a band of coal-measures coincides with, and may some day be reached along the line of the valley of the Thames, while some of the deeper-seated coal, as well as certain overlying and limited basins, may occur along beneath some of the longitudinal folds of the Wealden denudation."* This reference to the "deeper-seated coal" arose from his belief, when the paper was written (1855), that the coal-field of Namur was not on the same geological horizon as that of Hardingham in Boulonnais, a belief which he afterwards abandoned. However, what he (Mr. Holmes) wished to call attention to was that Godwin-Austen by no means attempted, by a detailed examination of the course of the various folds visible at the surface of South-eastern England, to predict the course of the ancient Palæozoic ridge and its associated coal-basins beneath the surface. Indeed, the way in which he refers to possible coal-fields in the valley of the Thames, a river which, from Windsor eastwards, flows through the midst of a broad synclinal fold of Cretaceous and Tertiary rocks, and to other possible coal-fields beneath the broad anticlinal of the Weald, seems to imply reliance chiefly on the general direction of the Palæozoic ridge, and but little trust in the evidence of surface-features. Naturally, therefore, he confined himself to broad and general statements as to direction. Indeed, the uncertainty of surface-indications as guides to the greater or less depth of the Palæozoic rocks under South-eastern England is very strikingly illustrated by the results of the deep borings in that region. The boring at Battle was begun in the lowest rocks visible at the surface east of Marlborough Downs, Salisbury Plain, and the New Forest, and in the centre of the great surface-anticlinal of the Weald.

* *Quarterly Journal of the Geological Society*, vol. xii., page 73.

Judging, therefore, from these circumstances, it might have been anticipated, on the hypothesis that the newer anticlinal was practically identical with the older one, that the Palæozoic ridge would be met with in that locality unusually near the surface. Similarly, it might have been expected that the borings in and near London, at Meux's brewery, Kentish Town, Turnford, Ware, Crossness, Streatham, and Richmond, in the broad synclinal fold of the London basin, would show Palæozoic rocks at a considerably greater depth. But, as is generally known, the results of these borings have lent no weight whatever to supporters of the practical identity of ancient and more recent geological folds. The Sub-Wealden boring near Battle, though begun in Upper Oolitic rocks, ended in Oxford Clay (Middle Oolite) at a depth of 1,905 feet. On the other hand, the borings in the synclinal of the London basin, after passing through an average thickness of about 1,000 feet of Cretaceous and Tertiary beds, all ended in either Palæozoic or Triassic rocks at that or a slightly greater depth, the latter appearing either directly beneath the Cretaceous beds, or, in two cases, beneath thicknesses of 87 feet and 64 feet of Oolites in addition. Thus, under the broad synclinal of the London basin, the Palæozoic rocks are unusually near the surface, and the Oolites, which would be naturally expected beneath the Cretaceous beds, were almost entirely absent. While, in the centre of the Weald anticlinal, the enormous thickness of the Upper and Middle Oolites alone prevented the boring, though almost twice the depth of the average of those near London, from showing the full thickness of the Oolite formation. Nothing can more strikingly illustrate the danger of undue reliance on surface-features as an index to the position of much more ancient subterranean folds in South-eastern England, whatever may be the case in northern France. In conclusion, it occurred to the speaker to remark that, judging of the unseen parts of the Palæozoic ridge and its associated coal-basins from what is visible, alike in England and in Belgium, one must not expect regularity either in the breadth or direction of the ridge, or in the size and occurrence of the coal-basins. For in the Palæozoic ridge one had an ancient rugged mountain-chain, while the coal-fields probably vary both in size and in their relations to this chain, at least as much as do those of Bristol, the Forest of Dean, and South Wales with the Mendip Hills and their continuation in Pembrokeshire and Glamorganshire.

Prof. BOYD-DAWKINS, F.R.S. (Manchester), said the Institution was to be congratulated on having received from one of the greatest authorities on mining in France a paper based upon his own special knowledge of that part of the country which joined immediately to our own, and he, too, felt to some extent fortunate because Mr. Bertrand's conclusion as regards the

coal-field of Dover and Somersetshire was one which entirely coincided with the view he communicated to the Royal Institution in 1890.* In that paper he called attention to the fact that in all probability the Dover coal-field continued to Calais and extended indefinitely eastward in the same direction. He would like to say a few words before discussing the question of folds, as to Godwin-Austen's meaning of the axis or ridge of Artois. He did not mean one anticlinal, but the complicated series of anticlinals and synclinals which with the faults form a line of weakness in the earth's crust, and which he traced all the way from the south of Ireland, through South Wales to the region of the Mendip Hills, and as far to the east as the region of Westphalia, and he pointed out that all along the great ridge of Artois, as he called it, workable coal-fields were to be found. Then he insisted upon another thing; he pointed out that this great line of weakness formed a ridge, and that that ridge formed a barrier against which the Secondary rocks were gradually thinned away. He also pointed out that this great barrier was marked by the line of the North Downs and by the arch which is represented by the Chalk of Wiltshire. Now, it seemed to him (Prof. Boyd-Dawkins) that in both these points Godwin-Austen's conclusions were amply and utterly proved to be true. Godwin-Austen's ideas were those which led in the first place to that very interesting boring at Netherfield which revealed the enormous thickness of the Secondary rocks—they were 1,905 feet, and when he said that the boring ended merely in the Oxford Clay he was giving proof that the Palæozoic rocks in that region (far away, as they would remember, from Godwin-Austen's line or ridge) were deeply buried beneath the Secondary rocks. The minimum depth at which the old Palæozoic plateau was buried in that region was certainly not less than 2,000 feet, and it might be considerably more than double that. Supposing they now turned to the second result of Godwin-Austen's principle. In 1886, as the result of Godwin-Austen's work and principles, he (Prof. Boyd-Dawkins) was led to select the site of the present boring at Dover—the boring which had been carried on by Sir Edward Watkin under his advice, and under the able management of Mr. Brady, and which had also at a later time the advantage of the advice and consultation of some of the leaders of mining in this country: he alluded more particularly to Mr. McMurtrie and some other gentlemen who were now present. What then should he say regarding the Dover boring as to the thickness of the Jurassic rocks in that place? We find that instead of 1,905 feet (the thickness of the Jurassic rocks in the district of Battle) they were

* *Proc. Royal Inst.*, 1890, vol. xiii., page 175, and *Trans. Manchester Geol. Soc.*, 1891, vol. xx., page 502, and 1892, vol. xxi., page 456.

here something over 600 feet ; in other words, the Secondary rocks, as they go from the direction of Hastings towards Dover, gradually thin off as Godwin-Austen said they would against this great ridge. The coal was struck exactly where Godwin-Austen said it was likely, where, by the thinning of these Secondary beds against the ridge in question, the coal existed at a workable depth beneath the surface. With regard to "workable depth"—1,100 feet as they all knew was not very much, and when they knew that the Coal-measures were struck at 1,113 feet below sea-water mark, they were of course dealing with Coal-measures which were well within the limit. The extent of Godwin-Austen's ridge of the Coal-measures somewhere along the line of the North Downs and the fact that the Secondary rocks thinned off against that ridge were proved beyond all doubt by the boring near Battle and the boring at Dover carried on by the Channel Tunnel Company. The boring at Calais was made in 1850, and, according to the account which was given a few years afterwards by Mr. Prestwich and that given by some other eminent geologists, the Coal-measures were discovered and struck at a depth close to the depth at which they were struck at Dover. In the present paper, Mr. Bertrand follows Mr. Gosselet in saying that there was no evidence that the Coal-measures were struck in that boring ; unfortunately, the specimens were lost after the Paris Exhibition, but happily Mr. Prestwich, who examined them with the late Élie de Beaumont, had no doubt that the specimens in question implied the existence of Coal-measures at Calais. The Calais boring then proved most satisfactorily the continuation of the South-eastern coal-field, as they might call it, from Dover and right under the channel in the direction of Calais. It was an undoubted fact that when they had great lines of disturbance, which were lines of weakness in the earth's crust, they would have the rocks which were folded afterwards and which rest upon those rocks tending to be crumpled parallel to the lines of fold. He ventured to think Mr. Bertrand had not clearly proved—at all events he would like to have a great deal more evidence on the point before accepting it—that the folds in the superficial rocks, taking it as a general principle, were identical in superposition with the folds which existed in the Palæozoic rocks ; and still less so when he knew that the Coal-measures and the Upper Carboniferous rocks which formed the ancient floor beneath the Secondary rocks were for the most part planed off to one dead level, composed of anticlines and synclines, and constituting practically one horizontal sunken plateau. He could not recognize that superficial folds on the surface gave any clue whatever to those foldings which were presented by the rocks which were buried and had been eroded and water-worn. This was not Godwin-Austen's view.

All he insisted on was the existence of the general principle. The line in question consisted not of one anticlinal or synclinal but it related to that grand series of plicated anticlinals and synclinals and folded rocks which constituted the axis of Artois, and which Godwin-Austen traced on the one hand from the Mendip region, under the Chalk in the North Downs until ultimately it reappeared in its proper position to the south of the Franco-Belgian coal-fields. He did not wish to detain them longer than he could help in discussing this very interesting and important paper, but if they took the principles of the folds laid down in it and applied them to the well-ascertained facts in this country he was bound to say these principles did not work so far as he knew the rocks in the south of England. There were no less than four axes, anticlinals and synclinals, massed together under the name of the axis of the Mendip Hills. Was there any indication in the rocks which cover up the eastern flanks of the Mendip Hills and cover the coal-fields too of any corresponding folds, anticlines, synclines, and others? He had no hesitation whatever in saying as far as he knew that country (and he knew it very minutely) that it was impossible to trace the complicated anticlines and synclines by corresponding folds in the rocks which cover them. Take another case. The area of London was a synclinal area; according to Mr. Bertrand's principle they ought to have a syncline corresponding with the synclinal area down below. What did they find? There was clear and absolute proof from the district of Richmond, from the series of observations taken as far north as Ware, that there were older rocks than Carboniferous, that is to say Devonian and Upper Silurian rocks. It was clear, therefore, that it was not a synclinal but an anticlinal fold, an anticlinal from which the Carboniferous rocks had been denuded, and in which merely the axis of older rocks were shown. With regard to these crucial points, they must have more evidence of the truth of the coincidence of the folds in the newer rocks with those of the older before they could apply them for practical purposes in this country. It remains now to consider the present position of the question of the buried coal-fields in southern England:—

- (1) The coal discovered at Dover was a good blazing coal, with lozenge-shaped cleat (the result of slight deformation by pressure of the original cubes). It was distributed in nine seams over 1 foot in thickness, of which the thickest was 4 feet, and presenting a total thickness of 20 feet 11 inches.
- (2) These seams were associated with sandstones and shales dipping at an angle of 1 in 28, and constituting measures 1,109 feet thick. This gentle dip may, as he (Mr. Boyd-Dawkins) had pointed out in 1892, be the result of the boring being in the centre of a syncline.
- (3) The few casts of *Calamites*, of *Lepidodendra* and ferns were too imperfect to allow of the

horizon of the coals being identified by the fossil flora. We still lacked the evidence necessary to establish the zones of vegetable life in the British coal-fields which would admit of such an identification. (4) The south-eastern coal-field to which they belong was, in his opinion, in the same relation to the ridge of Artois as the Somerset, South Wales, and Franco-Belgian coal-fields, on the northern side. It was probably continued eastwards under the Channel, in the direction of Calais and Belgium, and its westward prolongation in the direction of Somersetshire remains to be proved, along Godwin-Austen's line of the North Downs. (5) It was probably bounded to the south by the highly-faulted and folded older rocks, possibly containing locally small troughs of Coal-measures similar to those of Boulonnais, which pass southwards under increasing thicknesses of Jurassic rocks as at Battle in Sussex, and in the district south of the Mendip Hills. In this latter district there were a series of large east-and-west faults which threw down the Coal-measures, to the south, and which were represented by the smaller faults traversing the newer rocks. (6) The Silurian strata proved under the newer rocks at Ostend, and the Devonian and Silurian rocks struck in the lower valley of the Thames and along a line reaching from Richmond to the south, to Ware on the north, show that the northern boundary of the south-eastern coal-field is to be sought somewhere south of a line connecting Ostend with Richmond. (7) The plateau of buried rocks, including Coal-measures, lies in south-eastern England in the area of Dover and London, at about the same horizon from 900 to 1,100 feet below Ordnance datum, and the anticlines and synclines of which it is composed can only be ascertained by experiment. It was simply a question of fishing. (8) The discovery of the south-eastern coal-field is of great economic importance. It offers the long-wanted base-line for further exploration. It will probably, in the near future, convert the chalk cliffs into "studies in black and white," and turn the purely agricultural districts of Kent and Sussex into centres of busy industry like Liège. Down to the days of Elizabeth the sound of the forge echoed through the Weald of Kent and Sussex, and enormous cinder-heaps were formed, now grass-grown, or covered with trees. It will be a curious result of the whirligig of time, if, with coal for smelting near at hand, the old iron industry, which dates back as far as Roman times, should, through this discovery, again be revived.

Mr. P. S. REID (London) said, having made two journeys to the Continent with the late Mr. Godwin-Austen, and having also been accompanied by the late Prof. Bonamy Price on one of them, who was strongly impressed at that time by the opinions of Sir Roderick Murchison as to the futility of searching for coal in South-eastern England, he might

have some slight claim to a knowledge of Mr. Godwin-Austen's idea on the subject. He never, however, understood Mr. Godwin-Austen's theory to hinge upon a supposed series of folds more than that these so-called folds were evidences of seismic changes on the earth's surface, which produced the curious form of coal-fields extending as it does from Dortmund in Prussia into Belgium and thence into France, passing under the Straits of Dover and ending in the Radstock and Bristol coal-fields. In short, if he understood anything of Mr. Godwin-Austen's ideas on this point, it was clear to him that these coal-formations were originally horizontal, and that the curious state of squeeze, overlap, and disruption was entirely brought about by overwhelming seismic changes on the earth's surface. He might add that Mr. Price, impressed no doubt by a knowledge of Sir Roderick Murchison's views on this subject, did his best during a week's journey on the Continent to turn Mr. Godwin-Austen's views into ridicule, prompted by his intimate knowledge of his old college friend, who took all his banter in very good part. He never heard Mr. Godwin-Austen allude to the existence of an arch in the Oolitic or Cretaceous rocks, further than to express an opinion that the Coal-measures would be found below them, in the shape of a crushed basin unknown in the North of England, and dissimilar to any other of the coal-basins of England, with the exception of that of Radstock. The revelations of the coal-field at Dover, as shown by the boring carried on by the Channel Tunnel Company, do not show us such a crushed basin, and the first touch of the Coal-measures there, as well as the latest boring, whose cores may be seen at South Kensington, reveal the fact of an almost horizontal coal-field, with a complete absence of crush. This would, in his (Mr. Reid's) opinion, resemble more the existence of a coal-field similar to that of Yorkshire or Durham, than any accidented coal-field like that of Radstock or the Continental coal areas extending from Calais to Dortmund. The Coal-measures at Dover were cut into at 1,113 feet from the surface, and the first coal-seam was passed through at 1,139 feet, and from this point eleven seams were passed through terminating in the lowest at a depth of 2,181 feet, which, he estimated from information he possesses, would be found with a thickness of 4 feet of excellent coal. Of the other seams, he considered nine of them would be found workable with varying qualities of coal, but all of a class that would bear comparison with any of the seams of the known English coal-fields. This boring would have ended with a diameter of 7 inches had it not been tormented at the depth of 1,900 feet by a plastic clay which was melted by the attrition of the water in the hole until they were forced to diminish the size of the cores to 4 inches at the lower part of the hole, as the difficulty of cleaning out was great, and the cost of re-tubing the hole

looked formidable. He considered the discussion of Mr. Bertrand's paper at the present time, dealing as it did with much nebulous matter, as premature, and liable to misconception in an Institution like this, and certainly would prefer its being adjourned to such time as more solid information could be brought forward.

Mr. JAMES MCMURTRIE (Bath) said the views first expressed by Dr. Buckland, and afterwards by Mr. Godwin-Austen, Prof. Prestwich, and others, had been abundantly verified, and some amongst our own members who had expressed similar views long ago, were also entitled to be congratulated on the results. He would especially mention one name in connexion with this, one of the oldest members and one of the late Presidents of the North of England Institute of Mining and Mechanical Engineers, Mr. G. C. Greenwell, who in 1862, on his return from an inspection of the Belgian coal-field with Mr. Dickinson (H.M. Inspector of Mines), expressed a decided view in favour of the theory held by these other geologists, and, putting a pencil mark on a map in his possession immediately opposite Dover, said to him personally, "If ever coal is found in the South of England, that is where it will be found." It was remarkable that this opinion expressed in 1862 should have been so abundantly verified by the results of the Dover boring, and he thought Mr. Greenwell, too, was to be congratulated on the result. Having himself visited the Belgian coal-field, he was interested in this question, and was glad last year to have the opportunity of inspecting in London and Dover the whole of the cores, with which he was much impressed, for the discovery of nine seams had proved the reality of that coal-field, and this was still further emphasized by the discovery of a thicker seam—4 feet in thickness, which undoubtedly proved the existence of a valuable coal-field there. The promoters were also to be congratulated on the almost perfect horizontality of the strata, for, having examined core after core, he was unable to detect any evidence whatever of confusion or distortion. There seemed to be no evidence of folds amongst the strata, the beds were as level as the leaves of a book, a point of great importance to the future working of that coal-field. Although he had carefully perused Mr. Bertrand's paper, he was unable to grasp all the points raised. It would require a lengthened consideration of the contour-lines and levels on both sides of the Channel before the members could form an adequate opinion as to the facts brought before them. Two leading ideas seemed to be brought forward in the paper, one was the principle of the recurrence in the Secondary rocks of the folds and other effects which existed in the older rocks beneath; the second point appeared to be that the Belgian coal-field in coming westward divided into a series of troughs or basins

separated from each other by elevations of the older rocks. Taking the first of these points, there could be no doubt that Mr. Godwin-Austen's main theory was quite correct, viz., that the elevations of the older rocks which existed on the southern side of the South Wales and Somerset basin and on the southern side of the Belgian and French coal-fields were identical, and he thought Mr. Godwin-Austen's view was also correct (in a broad and general way) that the North Downs might be a later extension of the same range. But when they came to trace, by the more minute folds which Mr. Bertrand in his paper had endeavoured to make out, the history of the older rocks which lay beneath, they would agree with Prof. Boyd-Dawkins, and say that the case had not been made out to their satisfaction, and that they should reserve their opinion until the matter had been further investigated. There could be no doubt that ancient disturbances did act along certain lines at recurring periods; evidence of this was shown in the lines of disturbances which had come down to modern times. These seemed to follow in successive periods, and to indicate, as Prof. Boyd-Dawkins had said, a line of weakness in the earth's crust, and it was reasonable to expect that in the Secondary rocks of the South of England similar results might be found. In the French and Belgian coal-fields there was reason to believe that there were ancient elevations which preceded the Coal-measures; that in the Silurian and Devonian periods elevations took place which had the effect of creating a series of basins in which the Coal-measures were afterwards deposited unconformably; so that the upheavals which elevated the Coal-measures was not the first which had occurred but the second, the second being coincident with the first. And it would be not unnatural that in the Secondary period, in a lesser degree possibly, there might be some evidence of a third elevation, but speaking from the Somersetshire side of the question, he was bound to say they had little evidence, if any, in that direction. Having read this paper, he had turned his thoughts to the Mendip Hills, where evidence might be sought for, but only two indications occurred to his mind. One existed on the northern flank of the Mendip Hills, in a ridge known locally as Chew Down. Here there was a fold in the Lias exactly parallel with the Mendip Hills, probably indicating that there was some continuation of the folding action in the Secondary period. The other instance was at Old Down, where there was a synclinal fold which Prof. Boyd-Dawkins was well acquainted with, and which he (Mr. McMurtrie) believed to be approximately parallel to the Mendip Hills, and this also seemed to indicate the same thing. But when they turned attention to Frome, where the Mendip Hills were lost beneath the Secondary rocks, there was no evidence of folding whatever, the ridge

simply passing beneath the other Secondary rocks. There was one effect produced by this ancient range which ought to be mentioned:—At the close of the Coal-measures the ridge of the Mendip Hills had existed apparently as a ridge partially covered with water, some of its higher points being out of the water; but for the most part it had existed as a sunken ridge, the water rising high up the hill-sides; and these Secondary rocks appeared to have been deposited round the edges of the hills. On some of the lower elevations thin deposits were found of New Red Sandstone at one point, Lias at another, and at Frome a thin coating of Oolite, the great mass of the Secondary deposits being to the north and south of that range, but there was no folding. He doubted very much when they examined deposits as recent as Chalk, in the neighbourhood of Calais and Dover, whether they would find any physical results of the existence of that deep-seated ridge. With regard to the second theory advanced by Mr. Bertrand, that the Belgian coal-field was split up into a series of basins extending westward towards Calais, he (Mr. McMurtrie) had turned attention to the Somerset field to see if there were any indications of similar results, and he was bound to say that at present he knew of none. If the Belgian coal-field broke westward into a series of parallel basins one would expect to find traces of similar action in Somerset, and this might be found in other coal-fields lying to the south of the Mendip Hills; there was reason to believe such might be found, but at present they did not know of any. The Coal-measures on the northern flank of the Mendip Hills were so fully developed, and the seams so thick and numerous, that they presented no indication that they were the southern boundary of the Coal-measures; on the contrary, they were such as to lead them to hope for a continuance of those measures on the southern side of the hills. It was said that a small piece of coal was once found in the neighbourhood of Wells, but it was not conclusively proved, and all they could say at present was that there was no geological reason why a repetition of the field should not be found there. He would congratulate the Institution on having such a valuable paper, which, however they might look at it or differ from it, contained a large amount of information which would lead to good results hereafter.

Prof. HULL said he had read the paper, and was glad to find this subject (with which Mr. Godwin-Austen's name was so closely connected) was treated from the French side of the Channel. The author had grasped Mr. Godwin-Austen's ideas very clearly, and endeavoured to illustrate them by reference to the structure of the country on both sides of the English Channel. He fully concurred that the lines, the great axes of folding, of

different periods had been often repeated and particularly in the case of the Cretaceous period, the flexures which undoubtedly, in the South of England, followed the lines that were originally marked out (so to speak) at the close of the Carboniferous period, probably of the Permian; because he held that the east-and-west foldings were of pre-Permian age, that is to say, were immediately produced at the close of the Carboniferous period and followed by a vast amount of denudation before the Permian rocks were deposited; while the north-and-south foldings (which traverse the great South Wales and Somersetshire and the Forest of Dean coal districts, causing them to assume basin-shaped forms) was of later date—after the Permian period and before the Trias. He thought they had now sufficient ground for believing that the Palæozoic rocks below the London basin and southward really followed each other in successive order. He had felt recently very strongly that we ought to have all the borings that had been made, and that were being made from time to time, in the east and south-east of England laid down on maps, so far as they threw light on the structure of the pre-Secondary rocks. So that ultimately we, or those who succeed us, may be able to construct a geological map of the south, south-east and centre of England, such as would appear if all the Secondary rocks were stripped away.

The PRESIDENT said their thanks were especially due to Mr. Bertrand for having written this paper, and he was sure the discussion had been such that all of them must have enjoyed it. Although they were not probably quite alive to the whole of the details, he thought it must have been very interesting to them. He was afraid the state of the coal trade did not warrant more capital being brought into it. Posterity was to be congratulated, and he thought a time would come when coal in the South of England would be worked; but its value had yet to be tested. A seam of coal, 4 feet in thickness was, as they all knew, as regards thickness, very valuable; in fact they were working seams not more than half that thickness at present, consequently a 4 feet seam of coal, of the quality that had been stated, was a very valuable find. He thought they had a good deal more to learn with reference to the coal of the South of England, and that this paper would materially assist them. He proposed a very hearty vote of thanks to Mr. Bertrand for his very valuable paper.

Mr. McMURTRIE expressed his pleasure in seconding the motion, which was carried with acclamation.

Mr. MARCEL BERTRAND wrote that he wished in the first place to thank the Federated Institution of Mining Engineers for the insertion of his paper in their *Transactions*, and to thank the members present at the

meeting for their kindly and courteous reception of his communication. He considered it a great honour that his views should have been the subject of a discussion so brilliant and searching. He was by no means surprised at the objections which had been raised, or at the reservations which had been made with regard to his conclusions. He remembered the words of Lyell in the *Antiquity of Man* to the effect that these are difficult subjects, concerning which no man should write unless he is prepared to make mistakes sometimes. He would wish, however, mainly for the purpose of defining his views, to answer two of the objections which were raised by Mr. McMurtrie and Prof. Boyd-Dawkins. Firstly, as regards the fan, opening westwards, formed by the various secondary synclinal folds of the Valenciennes coal-basin (the most northerly folds ceasing to contain coal before the more southerly fold of the Pas de Calais). If that view were recognized as correct, it would in no wise imply that a similar phenomenon should recur symmetrically in Somersetshire. And after all it is a matter of merely secondary importance. The same thing cannot be asserted of the objection founded on the London basin, which is a synclinal basin superposed upon an anticlinal ridge of the older strata. But in his (Mr. Bertrand's) view the contradiction is more apparent than real, for the London Tertiary basin is not a single synclinal fold, but a composite depression, succeeded longitudinally by a whole series of folds. Doubtless these folds are so slight that it is quite possible to deny their existence, and in any case one can hardly plot them out definitely. And yet it is just these folds that one ought to know and to discuss for the purpose of applying the principle as he (Mr. Bertrand) understands it. Similarly the subjacent Palaeozoic ridge is a composite one, not a single anticlinal fold; the Secondary folds which furrow it no doubt correspond to the folds (more or less obliterated) of the Cretaceous and Tertiary strata, independently of the fact that the former underwent altogether a movement of uplift after Palaeozoic times, while the latter underwent a movement of depression after Tertiary times. If these vertical movements (compared elsewhere with secular oscillations) be not carefully separated from folding movements, the principle that has been enunciated becomes indefensible, and its untrustworthiness can then be demonstrated by appealing to scores of examples. It is just herein that he (Mr. Bertrand) has modified, as was so well said by Messrs. P. S. Reid and McMurtrie, the theory first set forth by Godwin-Austen: he (Mr. Bertrand) claims that it is not the movements as a whole, of the earth's crust, movements which vary unceasingly and yet are always complex, which are similarly reproduced along the same lines, but only the folding movements. The fold, which is the tectonic unity

recognized in mountain chains, would then have just as great an indicative value in plain country where its prominence, however, is often slight, as where it is masked by other movements. If, instead of considering an individual fold, we consider a group of folds, forming a basin such as the London basin or a dome such as the Weald, we shall of course find that our rule will not work, because, despite the coincidence of each several pair of unities, the subjacent group taken as a whole does not correspond to the superjacent group as a whole. If instead of Ariadne's thread for a clue, you take a rope to guide you, 'twill scarce help you out of the labyrinth.

Sir ARCHIBALD GEIKIE read the following paper on "The Work of the Geological Survey":—

THE WORK OF THE GEOLOGICAL SURVEY.

BY SIR ARCHIBALD GEIKIE, F.R.S., DIRECTOR-GENERAL.

Before geology became organized into a definite branch of science, men had begun to perceive that one fundamental requisite, as a groundwork for the study of the rocks of the earth's crust, alike in their theoretical and industrial aspects, lay in the delineation of the respective areas of these rocks upon maps. At first the maps so constructed were merely rough representations of the general distribution of the mineral masses. They were mineralogical, or as they were called then, geognostical, that is, they only aimed at an indication of the relative positions of the rocks at the surface. They made no attempt to show the structure and sequence of the various formations. It was not until the time of William Smith that geology was supplied with the means of determining the true succession of the stratified rocks, apart from mere lithological characters which had previously been the only guide. Well may we look back upon that great pioneer as the father of English geology. In every department of the science we may trace the direct or indirect influence of his fruitful labours. But in no branch of investigation has this influence been more profound than in geological map-making, and in the assistance which geological maps have furnished to the onward progress of the science. The earliest truly geological map, as distinguished from its geognostical or mineralogical predecessors, was the famous map of England, laboriously constructed by Smith himself after years of patient investigation, and published in 1815-1819. The appearance of this map marks an epoch in the history of the science. It showed for the first time how the successive stratified formations of the earth's crust could be recognized and traced, apart altogether from their varying mineral characters, and how the geological structure of one country could be logically compared with that of other countries. In fulness, accuracy, and artistic delineation, an enormous advance has been made during the last three generations in the construction of geological maps, but the initial impetus of this advance must unquestionably be traced to the early surveys of William Smith.

We are all more or less familiar with the important share which this country has taken in the development of modern geology. It is perhaps not so generally recognized how much the science has been aided here by the early delineation of the geological features of these islands upon maps. What William Smith did for England and Wales, Macculloch did for Scotland, and Griffith for Ireland. Macculloch's map, published in 1832, though less original than Smith's, and bearing more evident trace of the influence of the older geognostical school of observers, was a remarkable achievement for a single observer, in a region so complicated in its geological structure and, in the early decades of this century, so difficult to traverse. Griffith had the advantage of coming later into the field, when geological methods of observation had made considerable progress. His great map of Ireland, published in 1846, is consequently much more modern in its treatment of the subject. It will ever remain a monument of extraordinary industry, sagacious observation, and felicitous inference, employed in the investigation of a country where, save in a few detached areas, he was practically the first great pioneer.

But it was not only in the British Isles that the necessity for geological maps was recognized as a basis for scientific progress in the investigation of the earth's history. I need only refer to the first sketch of a geological map of France, Belgium, etc., by J. d'Omalus d'Halloy (1822), to the excellent map of France by Dufrenoy and Élie de Beaumont, 1840-42, and to the early maps of Desmarest, Dumont, Von Dechen, Naumann, and other cartographers in different parts of Europe.

Even the best of these early maps were confessedly mere outlines. Their scale was small, and their topography often meagre and even inaccurate. For geological research they were inadequate, while for industrial purposes they were entirely insufficient and even in some degree misleading. The connexion between geological investigation and many practical affairs in daily life had now begun to be perceived. In this country the first geologist who devoted himself to the development of this connexion was Henry Thomas de la Beche—a name which we regard with pride and affection as that of one of the greatest leaders of the science whom Britain has produced. Having begun to study the geological structure of Devon, Cornwall, and West Somerset, he became greatly interested in the many problems which the rocks of that region present. He saw that an accurate delineation of the courses of the mineral veins, elvans, and faults through the masses of killas and granite could not but be of the utmost service in the prosecution of the mineral industry on which the prosperity of the country so largely depended. Accordingly,

supplying himself with the Ordnance maps on the scale of 1 inch to a mile, he began, with a few assistants and at his own charges, to map the details of the geology. Impressed with the national importance of the work which he had undertaken, he made application to the Government of the day for assistance and recognition. In the year 1832 he obtained a small Parliamentary grant in aid, and in successive years he succeeded in so influencing the official mind in favour of the views which he advocated that in the end he had the gratification of establishing a Geological Survey of the kingdom as one of the scientific undertakings of the nation, with an affiliated School of Mines, a Museum of Practical Geology, and a Mining Record Office. His aim was to conduct the whole establishment on the basis of strictly scientific investigation, but to afford in every possible direction all the aid which geology could furnish to mining industry, engineering works, agricultural progress, and other practical affairs. This design, broadly conceived by him, was efficiently carried into execution. The Geological Survey which he founded grew under his fostering care and that of his successors, and became the parent and model of other national surveys which have since been organized so plentifully both in the Old World and in the New.

Without attempting to give, even in outline, a history of the progress of our Geological Survey, I propose to lay before you on the present occasion some details as to the nature and extent of the work that is now carried on by the Survey. The designs so ably planned by Sir Henry de la Beche were extended by his successor, Sir Roderick Murchison, and were further improved by my predecessor, Sir Andrew Ramsay. Since my own appointment as Director-General in 1881, I have been enabled to introduce other modifications that tend to still greater efficiency. But essentially the organization and methods remain as they were planned by the first founder of the service.

The Geological Survey is now divided into three distinct branches, one for each of the three kingdoms, but united and kept in organic connexion under one Director-General. Each staff has its separate organization, but its members may be interchanged. It consists of two grades: (a) district-surveyors, geologists and assistant-geologists, whose chief duty, under the superintendence of their director, is the preparation of the maps, sections, and memoirs; and (b) collectors who, under the supervision of the other officers, search for fossils and collect specimens of minerals and rocks for description and for exhibition in the museums. There is an office and library or museum in London, Edinburgh, and Dublin. Each branch has also its own headquarters with a small resident staff, the head office

for the whole Survey being the establishment at Jermyn Street. The total strength of the service in the United Kingdom, including the officers engaged in museum work, is at present 60. As the duties are practically the same in each branch of the Survey, I shall treat the whole as one service and describe its work under the following heads:—1st, mapping; 2nd, petrographical determination; 3rd, palæontological determination; 4th, the collecting of rocks, minerals, and fossils; 5th, the preparation of maps, sections, and memoirs for publication; 6th, museum work; 7th, general administration; and 8th, relations of the service to other Government departments and to the general public, as regards the furnishing of geological information.

I. MAPPING.

The first and most important duty of the Survey is to map in detail the geological structure of the country. When this task was first undertaken by De la Beche and his associates they employed the Ordnance Survey maps on the scale of 1 inch to a mile ($\frac{1}{63360}$) which had then been published for Cornwall and Devon. These early Ordnance sheets, however, were imperfect and incorrect in their topography, having been among the first undertakings of the Ordnance Survey, before methods of surveying had been brought to the perfection that has since been attained. The connexion between the Geological and the Ordnance Surveys was at first so intimate that the former was instituted as a subsidiary branch of the latter. The geologists belonged to the "Ordnance Geological Survey," and though they were never under military orders they wore a uniform. The only surviving relics of that connexion are some of the waistcoat buttons, which on festive occasions continued to be worn after the rest of the raiment had disappeared. But from the first, and up to the present day, the Ordnance maps have been the basis on which all the geological work has been conducted. We have heard much in the last few years of the inaccuracies and imperfections of these maps. But the experience of the Geological Survey does not bear out this charge. I do not suppose that the maps have ever been put to a severer test than by the officers of the Geological Survey, who have carried them into every nook and corner of the country, from coast-line to mountain-top, and have checked them in many ways while fixing the positions of geological lines. It is, of course, admitted that the old 1 inch maps are unequal in value, and frequently imperfect or even inaccurate in their topography. But since the Ordnance Survey was plotted on a large scale, the accuracy attained has been so great and so invariable as to fill my colleagues and myself

with admiration. It is on these most excellent maps that our geological lines are traced upon the ground, and on which they are ultimately engraved and published. So that although the old outward bond of connexion between the two surveys has long been severed, the relationship between them remains as intimate and cordial as it has ever been.

All the mapping of the Geological Survey is now conducted upon the Ordnance maps on the scale of 6 inches to 1 mile ($\frac{1}{10560}$). These maps were not available in England and Wales until about two-thirds of the country had been surveyed geologically, and it was only in the northern counties that they could be adopted. In Ireland, however, and in Scotland, they were obtainable from the commencement of the geological operations, so that the whole of the work has been conducted with them as a basis. It is impossible to over-estimate the gain, both in completeness and accuracy, from the substitution of a large-scale map in the general investigation of a complicated geological region. For example, no more admirable piece of geological mapping had ever been achieved when the Geological Survey maps of North Wales, by Ramsay and his colleagues, were published. That difficult region was surveyed on the 1 inch scale, and excellent though the work still is, it is far inferior to what the same band of intrepid mountaineers could have accomplished had they had the good fortune to be furnished with 6 inches maps. Occasionally, when the structure becomes excessively complicated and when its details require to be mapped out clearly to be intelligible, maps on the scale of 25 inches to a mile ($\frac{1}{2640}$) are made use of. Ultimately, however, all the work is reduced to the 1 inch scale, this being the scale on which the general geological map of the United Kingdom is published.

Let me say a few words about the actual methods of geological surveying. The question is often asked of us, do we bore or dig? and when we answer in the negative, an incredulous smile may often be seen on the face of the enquirer, who evidently at once begins to doubt the trustworthiness of any surmises we may make as to what lies concealed beneath the surface. In reality, however, a trained geologist can generally tell, with a close approximation to accuracy, the character and arrangement of the rocks underneath his feet. There are many indications to guide him which do not strike the eye of the ordinary observer. So far from being guess-work his conclusions are often based upon such an array of observed facts as to be irresistible. The first experience of a recruit who joins the service is to be trained in the practice of searching for geological evidence. He soon learns how unobservantly he had walked about before, and in how many ways he may detect indications of how geological boundaries run,

even when the rocks themselves may generally lie out of sight. He finds that moles and rabbits help him greatly by throwing up the subsoil for his inspection. The farmer assists him as he ploughs and drains the land. He is even indebted now and then to the grave-digger. Every ditch and cutting may be made serviceable for his purposes. Wells, quarries, pits, railway-cuttings, in short, every natural and artificial exposure of the rocks or of their detritus may furnish him with the information he requires. It does happen now and then that, after fairly exhausting the evidence, he has to confess himself puzzled. He cannot be quite sure how the rocks exactly lie and how his boundary-lines should be made to run. In such cases we have sometimes recourse in the Survey to the boring-rod, and by its means we have been able in one or two localities to prove the existence of formations of which no superficial evidence could be obtained.

A member of the Geological Survey may start fully accoutred for his work in the field without betraying by any outward visible token what is his handicraft. His maps are carried in a portfolio which slips into his pocket or hangs by a strap inside his coat. His hammer goes into a sheath and belt round his waist. His clinometer, compass, notebook, lens, pencils, and other small items are easily stowed away among his numerous and capacious pockets. Thus lightly equipped he may make his way over any kind of ground, and can spend a long day in the prosecution of his work.

Not only by minute observations of superficial detritus but by measurements of the dip of rocks, where these are exposed at the surface, the observer may form tolerably accurate conceptions of the nature and arrangement of the rocks underneath and of the depth at which any given stratum may be expected to be reached. Thus in questions of water-supply he may, from such superficial observations, predict with some confidence the distance to which a boring must be sunk before a certain water-bearing stratum will be reached.

(a) *Drift Survey*.—Geology had made considerable progress in the study of the solid rocks before much attention was paid to the looser superficial deposits. The Geological Survey in this respect followed the general rule, and for many years made no systematic attempt to represent the numerous and often complex accumulations of superficial materials. Some of these indeed were shown on the maps, such as tracts of blown sand and river-alluvium. But it must be remembered that in the south-western counties, where the Geological Survey began its work, and in those

where for many subsequent years this work was continued, superficial deposits are of such trifling extent and importance that they were not unnaturally ignored. Only after most of the southern half of England had been completed was it determined to map the surface-deposits with as much care and detail as had been expended on the older formations lying beneath them. It had been discovered that this course was necessary both on scientific and practical grounds. In the first place, these superficial accumulations contained the records of the later geological vicissitudes of Britain, and were beginning to reveal a story of the profoundest interest, inasmuch as it dovetailed with the history of the human occupation of the country. In the second place, it was recognized that in many various ways these surface-deposits had a direct and vital influence upon the welfare of the population. In agriculture, in water-supply, in questions of drainage, and of the location of dwellings, it was seen that a knowledge of the soils and subsoils, and of the formations from which these are derived, was of the utmost practical importance. It was therefore determined that thenceforth the Geological Survey should not only portray the lineaments of the solid earth, but trace out the drifts and other surface-deposits which, like a garment, overspread and conceal them. It was impossible at first to go back over the ground where the surface-geology had been omitted. But it was arranged that when the whole country had once been mapped those tracts should be re-examined wherein the superficial deposits had not been surveyed. And, in the meantime, over all new areas the survey was made complete by the tracing out both of the surface-deposits and of the older rocks below them.

No one who has not given some personal study to the complicated details of surface-geology can realize the amount of labour which the mapping of them often involves. The distinctions between the various superficial deposits, though real, are sometimes slight, and as sections are frequently few and wide apart, and the deposits so often occur in irregular patches, the ground has to be traversed with a detailed scrutiny which is generally not required for the older rocks underneath. Viewed broadly, the superficial accumulations are grouped and mapped by the Survey in two leading series. First come those which have resulted from the decay of rocks *in situ*, and then those of which the materials have been transported into their present positions.

1. The first of these two series, in so far at least as it is capable of being mapped, is mainly confined to the extreme southern fringe of England. All over the three kingdoms, indeed, the weathering of rocks

has for ages been in progress, and here and there, especially in the upland and mountainous districts, accumulations of rotted rock may be observed at the foot of the crags and on the slopes. But what can there be observed is only what has accumulated since the last glaciers and ice-sheets scraped the loose detritus off the surface to form parts of the great group of glacial deposits. South of a line, however, drawn from the mouth of the Severn to the mouth of the Thames, this country seems never to have lain under a mantle of moving land-ice, nor beneath a sea covered with drifting ice, though fragmentary sheets of old marine gravels cap many of the plateaux and traces of probable ice-transport are found on the south coast. The surface in this southern tract has thus been left undisturbed for a great length of time. Its rocks have slowly decayed and their *débris* have gradually accumulated above them, with only such slight transport as may have been due to the washing of rain and the sifting of wind. We see the results of this prolonged waste in the brick-earths, clay-with-flints, and other deposits, that form so marked a feature on the Chalk Downs. From the Chalk districts westward across the Jurassic, Devonian, and older formations, even to the farthest headlands of Cornwall, every rock is more or less buried under a covering or "head" of its own decayed material. Sometimes, as on the Oolitic strata of Dorset or the killas of Cornwall, this upper decayed layer may be traced as a yellow or orange band, varying from a few inches to many feet in thickness, conforming to the shape of the surface, and presenting a singular contrast to the black horizontal shales of the one coast and the purple vertical slates of the other. In the interior, where natural or artificial exposures of the rock are sometimes scarce, the spread of this mantle of disintegrated material is a serious impediment to the mapping of what lies underneath it.

2. But it is the second or transported series of surface-deposits which chiefly engages the attention of the Survey. In mapping it an effort has been made to discriminate each of its members, to trace out their relations to each other, and to ascertain the connected geological history of which they are the records. At the same time, regard has been had to the practical applications of the enquiry, the connexion between soil and sub-soils has been kept in view, pervious and impervious deposits have been distinguished, and an endeavour has been made to collect and embody on the maps as much information as possible regarding the practical bearings of the surface-geology.

As an illustration of the detail into which the mapping in this department has been carried, I may mention that under the single term

"alluvium" we now discriminate and indicate by separate signs and colours a large number of distinct deposits. Thus, there is a group of freshwater alluvia, beginning with the present flood-plains of the rivers and rising by successive terraces to the highest and oldest fluvial platforms. Deposits of peat are separately traced, and tracts of blown sand are likewise mapped. Then there is another series, of marine alluvia ranging in position and age from the mud of modern estuaries and the sands of flat shores exposed at low water, through a succession of storm-beaches and raised beaches, up to the highest and most ancient marine terraces 100 feet or more above the present level of the sea. Regarding the origin of some of the high-level gravels, there is still much uncertainty, but the Survey has taken the first necessary step for their ultimate explanation by carefully tracing their distribution on the ground.

But the most abundant and complex group of superficial deposits is that which may be classed under the old name of Glacial Drifts. These have been mapped by the Survey in detail, and much of the progress of glacial geology in this country has been due to the sedulous investigation thus required. The ice-striae on the solid rocks have been observed over so much of the country, that maps may now be constructed to show both the march of the main ice-sheets and the position of the later valley-glaciers. The various boulder-clays have been mapped, likewise the sands and gravels, the esker-drifts, the marine shelly-clays, and the distribution of erratic blocks. A vast amount of information has thus been collected regarding the history of the Ice Age in most parts of the country. Even in the southern or non-glaciated fringe which I have already referred to, one of the members of the staff has been able to detect interesting evidence that though beyond the limits of the northern ice-sheets, this southern tract nevertheless had its frozen soil and its rafts of coast-ice. In the north of Scotland proofs have been obtained of the long-lingering of the ice-fields in that region; while in all the mountainous districts the gradual retreat of the valley-glaciers, as the climate grew milder, has been shown by mapping the successive crescents of moraines, one behind the other, up to the very base of the crags that supplied their material.

The survey of the superficial deposits thus combines a wealth of geological interest with a great deal of practical value. The geologist may find in it the solution of some problems and the presentation of many more. While the farmer, the water-engineer, the builder, and the sanitary inspector may each in turn gain some practical information from it for their guidance.

(b) *Solid Geology Survey*.—By way of distinction, the mapping of the formations of every age that lie beneath the recent superficial deposits is known as the survey of the “solid geology.” The object in this part of the work is to represent on the maps the exact area which every formation or group of rocks occupies at the surface, together with all indications that can be obtained of its structure, such as its variations of inclination, its changes of lithological character, and the dislocations by which its outcrop is affected. While the basis of the work is rigorously geological, an effort is made to ascertain and record any facts which may have an industrial bearing, such as the presence of useful minerals, or the depth and variations in thickness of water-bearing strata. The large scale on which the Survey is conducted allows much local detail to be inserted on the maps both of a scientific and a practical nature.

In those districts of the country where the rocks have long been well-known and where the geological structure is simple, the duties of the surveyor are comparatively light, though it often happens there that the simplicity of the solid geology is compensated for by a great complexity in the overlying “drifts.” Yet even among formations that have long been familiar, the diligent surveyor may generally glean new facts, or be able to throw new light on facts which were already well-known. Thus only a few years ago, even in a formation so well worked out as the Chalk, one of the members of the Survey detected the existence of a phosphatic deposit like those which have long been worked in the Chalk of Belgium and France.

It is where the rocks are varied in character and complicated in structure that the full working power of the Survey is called out. Take, for example, such a tract as that of the North-west Highlands of Scotland. In that region the mere physical difficulties of the ground are great. With a topography of exceeding ruggedness and sometimes of great elevation, with a climate wetter and more boisterous than almost any other to be met with in these islands, and with quarters often of the most uncomfortable description, the geological surveyor needs all his enthusiasm and ardour to carry him bravely through these preliminary obstacles. But when he comes to unravel the structure of the rocks he finds it almost incredibly complex. Day after day he may be seen traversing the same face of cliff, creeping from crag to crag, hammer in hand, heedless of the eagle that sweeps out from its nest above him or the red deer that breaks from its covert in the rocks below, his eye intent on the face of each scar and cleft as he pauses to take his measurements or set down his notes on map and notebook. He encounters varieties of

rock which he may be unable to identify by any of the simple tests that can be applied in the field. He takes chips of these home with him, and if they still offer difficulties he sends them up to the office, where they are cut into thin slices and examined with the microscope, or are chemically analysed, and a report embodying the results of the examination is returned to him for his guidance, while he may himself study the slides and verify or check the observations which the petrographer has made upon them. Again, he may detect in other rocks traces of organic remains, the importance of which he at once perceives. Such specimens as he can himself collect are sent up to the head office for determination by the palæontologists, and upon their decision may depend the name to be assigned to the fossiliferous rock and the colour and sign whereby it is to be designated on the published maps.

The complication of the "solid geology" in these north-western regions is enough to tax to the utmost the capacity and the energy of the surveyor. But he has besides all this to keep his eye ever open to all the varying problems presented by the superficial deposits. The ice-striae on the rocks, the scratched stones high on the mountain-sides that mark where the till once lay, the varieties of boulder-clay, the sand and gravel eskers, the scattered erratic blocks and the detection of their probable sources of origin, the moraine mounds fringing or filling the bottom of the glens, the sheets of flow-peat and the rugged peaty mantle that hangs down from the cols and smoother ridges, the recent alluvia and the successive stream-terraces, the lines of raised beach and the estuarine silts—all these and more must be noted by him as he moves along and must be duly chronicled on his map and among his notes.

It is obvious that the progress of a surveyor in such ground cannot be rapid. If the work is worth doing at all, it should be well done, and if well done, it must be done slowly and carefully. It is evident also that the total area surveyed in a year, if given in square miles, affords no guidance whatever as to the amount of labour involved. There may be a hundredfold more exertion, physical and mental, required to complete a single square mile in some districts than to fill in ten square miles in others. It is customary in the service to estimate not only the area annually surveyed by each officer in square miles, but also the number of miles of boundary-line which he has traced. The ratio between these two figures affords some measure, though an imperfect one, of the comparative complexity or simplicity of the work. In simple ground a surveyor need have no difficulty in mapping from 70 to 100 square miles in a year, each square mile including from 3 to 6 linear miles of boundary. But in

more rugged and difficult districts it is often impossible to accomplish half of that amount of area. In these cases, however, the ratio between area and boundary-lines usually rises to a high proportion. Thus last year, in Argyllshire, the average number of linear miles of boundary-lines was as much in one district as 17 miles in every square mile surveyed.

In mining districts an endeavour is made to express on the maps the positions of the outcrops of all seams and lodes, the line of every important fault and dyke, with the place of such faults at the surface, and where they cut different seams underground. For the information necessary to record these data we are mainly indebted to the owners and lessees of the mines and pits, who, as a rule, most generously give us every assistance. Details as far as possible are inserted on the 6 inches Ordnance sheets. Copies are taken of borings and pit-sections, and notes are made regarding variations in the character of the seams or lodes from one part of a mineral field to another. At the same time the district is surveyed in the usual way, and by exhausting the surface-evidence the surveyor is not infrequently able to supply important additional information beyond what can be obtained from the mining-plans.

It is the necessary fate of all geological maps to become antiquated. For, in the first place, the science is continually advancing, and the systems of arrangement of the rocks of the earth's crust are undergoing constant improvement, so that the methods of mapping which satisfied all the requirements of science thirty years ago are found to be susceptible of modification now. In the second place, in the progress of civilization, new openings are continually being made in the ground, wells, roads, drains, railways, and buildings are being constructed, whereby fresh light is obtained as to the rocks below. Geological lines which were traced with imperfect evidence can thus be corrected, and new lines which perhaps were not suspected can be inserted. If this kind of obsolescence overtakes geological maps even where only superficial openings are concerned, still more does it affect those which depict the structure of mineral fields still actively worked. The geological maps of Devon, Cornwall, and South Wales, made more than half a century ago by De la Beche and his associates were for their time admirable in conception and excellent in execution. Nothing approaching to them in merit had then been produced in any part of the world. But the mineral industry of the country has not been standing still all these years. Enormous progress has been made in working the ores of the western counties, and in developing the great South Welsh coal-field. Yet the maps remain as they were

originally published. The Geological Survey has of itself no power to undertake revision, and much as we would like to see all the mineral fields re-surveyed and brought up to date, we cannot go faster than Parliament will sanction or the Treasury will authorize. Two years ago, in response to an important memorial from South Wales, we received instructions to commence the re-survey of that coal-field, and the work is now in active progress. I trust the day may not be distant when similar revisions will be made of the other mineral-fields which were surveyed many years ago on imperfect 1 inch maps.

The re-surveys of the mineral districts can now be carried out on the 6 inches scale with a completeness and accuracy unattainable when the original surveys on the 1 inch scale were made. In some cases the maps of mining districts have been published on the 6 inches scale, but where the sale is likely to be small, instead of incurring the heavy expense of engraving the 6 inches sheets, we issue manuscript copies of these sheets at the cost of manual transcription. As an illustration of the kind of work undertaken by the Survey in the mining districts, I may refer to the Maps, Sections, and Memoir of the Yorkshire coal-field. There is no reason, save one of expense, why all the mining districts of the country should not be similarly treated.

Though systematic re-surveys are not undertaken by the Survey without express sanction, it is customary to make minor corrections which from time to time may be required in the published maps. Those counties in the south and south-west of England of which the superficial deposits were not originally mapped are now undergoing revision for the "Drift Survey," and advantage is taken of the re-examination of the ground for the insertion of the surface-geology to make any needful alteration in the lines of the solid geology.

II. PETROGRAPHICAL WORK.

In the earlier days of the Geological Survey each member of the staff determined for himself, by such tests as he could apply, the various rocks encountered by him in the field. Only in rare cases were chemical analyses made for him. The study of rocks had fallen into neglect in this country, being eclipsed by the greater attraction of the study of fossils. The introduction of the microscope into geological investigation has, however, changed this apathy into active interest. It is now recognized that apart from mere questions of nomenclature, rocks contain materials for the solution of some of the most important problems in physical geology. Accordingly, microscopic enquiry has in recent years been

organized as one of the branches of the Geological Survey, and now affords constant and material aid in the progress of the mapping. Chemical analyses are likewise made, so as to afford all available information as to the composition of the mineral masses encountered in the field.

When an officer engaged in mapping meets with rocks which present difficulties, either as to their classification or as to their bearings on the structure of the ground, he takes specimens of them which he numbers consecutively and sends up to the petrographer at the office, who enters them in a book under the name of that officer, and keeps a record of the destination of each. Those specimens which are selected to be sliced are numbered consecutively in the order in which they are cut, and are entered in books kept for the purpose. When they have been microscopically studied, described, and named, they are again entered in two distinct catalogues, one of which is arranged according to the sheets of the 1 inch map and the other according to petrographical types. Every sliced specimen is thus entered four times, and every specimen sent up for examination (whether sliced or not) can at once be found. A report is made out by the petrographer and sent back to the officer, who is thus put in possession of all the details which can be furnished to him regarding the rocks about which he needed assistance. In many cases the thin slices are also sent to the surveyor, who often spends his evenings in their study.

The original specimens from which the thin slides have been prepared are carefully kept in cabinets, so that if any accident should befall a slide a new slice can at once be cut. The mounted slides are arranged in separate cabinets. A large number of such slides have now been accumulated. From Scotland alone upwards of 5,000 have been determined, and are ready for reference at any moment.

But besides assisting the field-work, the petrographers are engaged in determinations required for the arrangement of rock-specimens in the museums at Jermyn Street, Edinburgh, and Dublin. The collectors are employed under the supervision of the surveying officers to make illustrative series of specimens of the rocks of each district. These are sent up to the office for examination and for insertion in the museum. In the course of the research thus imposed on them, the petrographers are from time to time enabled to make important original contributions to petrographical science. Moreover, they confer in the field with the officers who are engaged in mapping, and sometimes in concert with them make observations which are embodied in conjoint memoirs on the geology of the several districts.

III. PALÆONTOLOGICAL WORK.

In a country where the geological formations are to a large extent fossiliferous, it is necessary to pay close attention to the organic remains found in the rocks, to collect specimens of them, to determine these specifically, and to regulate thereby the geological boundary-lines upon the maps. The duty of examining and reporting upon the fossils is entrusted to the palæontologists, who occasionally visit the field, but are mainly engaged at the museums. With reference to the exigencies of field-work a somewhat similar system is followed with regard to fossil evidence as in the case of the petrography, though the same minute detail is not necessary. The officer, when in doubt about any species, the names of which are needful in separating formations and drawing their mutual boundary-lines, collects specimens of them and sends them up to the office for identification. They are compared by the palæontologist with published descriptions and named specimens, and a list of their specific names (as far as they can be made out) is supplied to the surveyor.

Besides such specimens as may require to be identified in the course of the mapping, full collections from the formations of each important district are made by the collectors under the guidance of the officers by whom the district has been surveyed. Every specimen is numbered and registered in the collector's book, so that its source and destination can at once be found. Lists of the fossils are drawn up by the palæontologists for insertion in the published memoirs. A selection of the best specimens is placed in the cases, drawers, or cabinets of the Museum. Fortunately in the case of the palæontologists also, though much of their work is necessarily of a routine official character, opportunities are afforded to them of making interesting and important additions to palæontological science. It was from this department of the Survey that Edward Forbes produced some of his best work, that Salter made his fame as a palæontologist, and that Professor Huxley enriched geological literature with his memoirs on Silurian crustacea, Old Red Sandstone fishes, and Triassic reptiles. Within the last few months fresh distinction has been won by one of the staff of the same department from the investigation and restoration of a series of remarkable reptiles from the Elgin Sandstones.

IV. COLLECTING WORK.

From what I have already said it will be seen that systematic collection of the minerals, rocks, and fossils of the country is an essential part of the operations of the Geological Survey, and is made to aid the progress of the mapping and the completion of the illustrations of British

geology in the museums. Each branch of the Survey has its collector, who moves from district to district as his services are required. When he begins work in any area, he is supplied with a map on which the field-officer who surveyed it has marked every locality that should be searched, and also with a list of these localities, giving local details as to the rocks to be specially examined and the kind of specimens to be looked for and collected. When necessary the surveyor accompanies the collector to the ground and starts him on his duties. Every specimen which the collector sends up to the office has a number affixed to it, and is entered in the lists, which are also at the same time transmitted to headquarters. The specimens are then unpacked and treated by the palaeontologists or petrographers, as the case may be, in the manner already indicated.

V. PREPARATION OF MAPS, SECTIONS, AND MEMOIRS FOR PUBLICATION.

The results obtained by the Geological Survey are made public in three forms: Maps, Sections, and Memoirs, to which may be added the arrangement of specimens in the three museums, with their diagrams, handbooks, and other explanatory matter, and also the original papers, which lying often beyond the scope of the Survey's publications, are prepared by members of the staff and, with the consent of the Director-General, are communicated by them to scientific societies or journals.

(a) *Maps*.—Every surveying officer is responsible for keeping his 6 inches field-maps inked-in and coloured-up, so that if required to be exchanged with his colleagues they shall be clear and intelligible. He is likewise required to prepare duplicate copies of these field-maps, which when completed, are transmitted to the office and are kept there for consultation by the public.

As I have already stated, 6 inches maps of some of the mineral-fields have been published. These have been prepared by the officers who surveyed them, the geological work being put on a dry impression from the plate of the Ordnance map, which is then sent to the Ordnance Office to be transferred to an electrotype of the plate. In a few cases, also, maps on this scale, where the geology is of special interest or complexity, have been prepared and published. But for the country at large it is not desirable to publish maps on so large a scale as that of 6 inches to a mile. Over all the counties which have been surveyed on that scale, MS. copies of the 6 inches maps can be obtained by the public, at the mere cost of manual transcription from the duplicate copies retained in the office.

The work surveyed by an officer on the 6 inches scale is reduced by him upon a dry impression of the 1 inch Ordnance map. A single 1 inch sheet may comprise the work of half a dozen surveyors, and in that case the sheet is passed from one to another, each adding his own share. The completed dry proof is then checked at the office and is sent to the Ordnance Survey to be engraved on an electrotype copperplate specially prepared for the purpose from the original Ordnance plate. After the final corrections have been made in the engraved map and the scheme of signs and colours has been engraved on the margin, a copy of this map is coloured as it is to appear on publication, each surveyor again taking the portion for which he is personally responsible. The scrutiny involved in this process serves generally to detect any errors that may have previously escaped notice. This original coloured copy remains as the standard to which all subsequent copies of the same edition of the map are made to conform.

When finally checked and approved, the original coloured copy is sent to the colourists, who colour all the maps by hand, the work being done by women. Experiments were tried some years ago as to the feasibility of producing the Geological Survey maps by colour-printing. But with our system of engraving it was found impossible at the Ordnance Survey Office to ensure sufficiently accurate registration, and there was the further practical difficulty that so large an impression of each sheet would require to be printed off that a large stock would remain on hand, and new editions and alterations of the maps would be impracticable for many years. The original system has therefore been retained. It has this great advantage, that by keeping the supply of copies of each sheet just sufficient to meet the demand of the public, we are enabled to make any alteration of a map which from time to time may be found to be necessary, without the loss involved in cancelling a large stock of copies.

Some idea may be formed of the nature of the colouring work of the Survey maps from the fact that upwards of 180 different tints and combinations are employed to denote the various kinds of rocks separately discriminated on the maps. It is difficult to find colours distinct from each other, yet harmonious, and that will not fade on exposure. To guard as far as possible against the risk of fading, every colour is also distinguished by its own symbol, which is legibly engraved where the colour occurs on the map.

Two editions of the maps of England and Wales are now issued for those districts of which the Drift survey has been completed. One of these editions shows all the superficial deposits, and only so much of the



underlying formations as lies bare at the surface. The other edition presents the underlying formations as these would appear if the superficial accumulations could be stripped off. Each of these editions has its value for special purposes. In all questions of sanitation, water-supply, agriculture, and building, it is obviously the Drift edition that should be consulted, while, on the other hand, where the information desired has reference to what lies deeper beneath the surface, as in the sinking of deep wells and mines, it is the Solid edition that will be most usually consulted. The difference between the two is merely one of colouring, for they are printed from the same copperplate, and as far as the engraving goes are exact duplicates.

The prices of the maps are regulated by H.M. Stationery Office, and are fixed according to the amount of colouring work upon them. In England and Wales, full sheets usually range from 8s. to 8s. 6d. and quarter-sheets from 1s. 6d. to 3s. In Scotland and Ireland, the sizes of the maps are different, but their prices are calculated on the same scale, being in Scotland from 4s. to 6s., and in Ireland (where the sheets are similar in size to the English quarter-sheets) from 1s. 6d. to 3s. In some cases the price at which a map is sold is less than the cost of colouring, but it is estimated that the excess of selling price beyond that cost in other cases will compensate for this loss.

The total number of 6 inches maps published by the Geological Survey up to the present time is for England and Wales, 217 sheets; Scotland, 130 sheets; Ireland, 10 sheets. The number of 1 inch whole-sheets and quarter-sheets published for England and Wales amounts to 258; 142 of these are as yet published only as "solid" maps; 89 are issued in two editions, "solid" and "drift;" of 23 only the "drift" edition is published. Four quarter-sheets of the map of England yet remain to be published, but will be issued this year. The number of sheets published of Scotland is 48, and of Ireland 205. The whole of Ireland has been completed and published. Every effort is now being made to complete at as early a date as possible the survey of Scotland, but the extraordinary complication of the geological structure of the Highlands, being far greater than was ever anticipated, renders the progress less rapid than could be wished.

The desirability of having a general geological map of the country on a smaller scale than that of 1 inch to a mile has long been recognized. When the mapping of England was completed, advantage was taken of the existence of an index Ordnance Survey map on the scale of 4 miles to an inch. This map, based on the old 1 inch maps, had been laid aside

incomplete by the Ordnance Survey, but it was likely to be so useful for geological purposes that at my request it was finished at Southampton. The work of the Geological Survey is now being reduced upon this map, of which there are in England and Wales 15 sheets. Four of these sheets have now been published with the geology, embracing the east of Yorkshire and the southern counties, from Essex to Torquay. Other sheets are in progress, and the map when completed will present at a glance a clear and vivid picture of the geological structure of the whole country.

The value of reduced index-maps for geological purposes was recognized long ago by the preparation of a general map of Wales. When the Geological Survey of the Principality was finished the whole work was reduced to the scale of 4 miles to an inch and engraved in six sheets, which include parts of the West of England. This map has been on sale for many years.

(b) *Sections*.—A geological map can for the most part express only what lies at the surface, though it may afford information, more or less definite, as to what lies below. To supplement the map it is needful to construct sections to show the arrangement of the rocks beneath the surface. A complete and detailed map should contain sufficient data to allow of such sections being plotted in outline, but these details can usually be filled in only from the notes of the sections examined in the course of the mapping. Two kinds of sections are prepared and published by the Geological Survey—vertical and horizontal. They are drawn to scale, and engraved and published in sheets measuring 3 feet by 2 feet. But besides these, numerous measured and also diagram-sections are inserted into the text of the printed Memoirs.

The Vertical Sections are drawn usually on the scale of 40 feet to 1 inch, and are prepared almost entirely to illustrate the succession of strata in the coal-fields. Each sheet generally contains more than one section. The materials for the plotting of these sections are sometimes obtained by actual measurements taken by the surveyor himself, but more commonly are supplied by the lessees or managers of the collieries. Sometimes tables of comparative sections are given, in illustration of variations in character and thickness between the seams of coal, ironstone, or limestone in different parts of the same mineral field.

Occasionally, where a group of strata, though of little industrial importance, possesses great geological interest, a vertical section of it has been constructed and published in the same style as the coal-field sections.

In this way we have issued some useful sections of the Jurassic rocks in Eastern Yorkshire, of the Lower Lias and Rhætic rocks in the West of England, of the Tertiary strata in the Isle of Wight, and of the Purbeck group in Dorset.

Altogether 87 sheets of Vertical Sections have been published for the three kingdoms. The price of each sheet is 3s. 6d.

The Horizontal Sections have always been an important feature in the work of the Geological Survey. De la Beche, recognizing the practical disadvantages arising from the construction of sections without any regard to the proportion between height and distance, instituted the practice of drawing them on a true scale. He adopted the scale of 6 inches to a mile, and invented a system of patterns for the different kinds of rock, which, as he was himself an artist, are appropriate and effective, for they represent in no small measure the general structure of the rocks. The institution of such sections, in lieu of the distorted diagrams too generally employed, was of great service to the Survey itself and also to the progress of geology; for it served to correct the evil influences of distorted drawing, with regard not only to geological structure but to the true forms of the ground.

When a line of section was chosen and drawn on the 1 inch map, it had to be measured on the ground with chain and theodolite. This was the invariable practice until the 6 inches contoured Ordnance Survey maps came into use. With these maps as a basis, the laborious process of chaining the sections is no longer required. The section-lines are drawn on these maps and the sections are plotted from them. The contour-lines and bench-marks allow the line of the surface to be traced with a close approximation to accuracy. But in order to ensure final correctness of detail, the ground is gone over with the section in hand and each little feature is then put in.

The sections start from Ordnance datum (mean sea-level), but where the ground is low and there is consequently not room to express what is known of the geological structure above that datum, the lines are prolonged below it. The same practice is also followed in mining-districts. An effort is made to illustrate every great district of the country. Each geological formation, as it varies from one point to another, is crossed by lines of section, so that by comparing these the changes in that formation from district to district can at once be seen. The length of each section varies indefinitely with the nature of the ground, many of them being upwards of 100 miles in length. Thus a series of sections runs from Anglesey

and the coast of Merionethshire, across the mountainous ground of North Wales, to the plains of the Midlands. Another group crosses from the central counties to the South Coast. A connected chain of sections traverses the breadth of the island from Liverpool to the coast of Yorkshire.

As an illustration of the character of these sections and their usefulness in correcting popular misconceptions as to geological structure and form of the ground, I may refer to that which runs from Leicestershire to Brighton and passes through London (sheet 79). What is called the "London basin" is by many people regarded as a deep trough of clay, with the Chalk rising steeply from under it both to the south and north, and we may see this conception embodied in actual diagrams in text-books and elsewhere. But in reality both the London Clay and the Chalk are so nearly flat that their inclination can hardly be detected except by careful measurement. And the section, accurately plotted from borings and well-sections, shows them apparently horizontal, though on further inspection we find that their line of junction, which is well above the datum-line at either end, lies some way beneath it in the centre.

The Horizontal Sections are engraved on copper and published in sheets, each of which, if the ground be low, may include six lines or 36 miles of section. The same continuous line of section may thus extend over several sheets. Small explanatory pamphlets are published with these sheets, giving general information as to their formations and their local peculiarities. Each sheet of horizontal sections is published at the price of 5s. In all 191 sheets of such sections for the United Kingdom have been issued.

Besides the usual horizontal sections on the scale of 6 inches to a mile, occasional sections on a larger scale are prepared to illustrate the geological structure of particular localities. In this way the coast-line of Cromer and Yarmouth has been represented in detail, and its numerous features of geological interest have been inserted so as to exhibit a kind of picture of the arrangement of the strata in these changing cliffs. Portions of the coast-line of Dorset and of the Isle of Wight have been similarly treated.

(c) *Memoirs*.—Obviously, in the course of a geological survey, a large amount of detailed information is collected which cannot find a place either on the Maps or the Sections. This material embraces much local detail and a large body of evidence which is of importance in general geological enquiry. It can only be properly used by being

arranged, condensed, and printed. The issue of Memoirs of its work has been from the beginning one of the chief occupations of the Geological Survey of the United Kingdom. The form in which these publications have appeared has varied. De la Beche's plan was to publish volumes of General Memoirs embracing descriptions of particular regions and also essays on special branches of geological enquiry. His own memoir on the geology of Cornwall, Devon, and West Somerset is an admirable example of his method, and has long taken its place among the classics of English geology. There were practical difficulties, however, in the way of continuing his method when the staff increased, and the literary labour had to be shared by a number of observers, who were, in many cases, more willing to wield their hammers than their pens. When Murchison succeeded to the charge of the Survey, he sought to avoid these difficulties by instituting the practice of accompanying every sheet or quarter-sheet of the 1 inch map with an explanatory pamphlet, giving the chief data on which the map had been constructed, with references to the best sections, lists of minerals and fossils, and information as to the geological structure of the ground. These pamphlets, containing essential details only, were to be eventually condensed and collated by the Local Director, so as to form a generalized view of each important geological region. This scheme was well conceived, and with some modifications rendered necessary by the progress of the Survey, has been carried out ever since. It is not always possible or desirable to prepare a separate explanation for each sheet or quarter-sheet, for much reduplication of geological information would thereby be involved. Several quarter-sheets or sheets may be described together in a single Memoir.

Each surveying officer is expected to contribute the account of the area mapped by him. Where more than one surveyor has been engaged on a map or district, the accounts furnished by the several officers are collated and edited in the office, and are published generally in paper wrappers and at a low price.

Occasionally these Memoirs, when dealing with an important district, have been expanded beyond the limits of mere Sheet Explanations, and have taken the form of thick octavo volumes. Such, for instance, are the Memoirs on the Yorkshire Coal-field, on North Wales, on the geology of the Weald, on the geology of London, and on the Isle of Wight.

The chief literary work on which the staff of the Survey are now engaged is the preparation of the General Memoirs or Monographs to which the Sheet Explanations were designed to be preparatory. It appeared to me that the most generally useful plan on which these could be

prepared was to make them fundamentally stratigraphical, in other words, to devote them to a description of the various geological systems which are embraced within the British Isles, and to show not only what has been done by the Survey in each of these systems, but what has been ascertained by others. Each monograph should thus be a compendium of all that is known of its subject up to the date of its publication. The information obtained by the Survey in its progress is necessarily scattered through many maps, sections, and memoirs. The work of the service would be incomplete and difficult of consultation if it were left in this disseminated state. It needs to be gathered together, arranged, and put into connected form, so as to present an intelligible account of the geology and mineral products of these islands. The task is a heavy one and cannot be speedily finished. But satisfactory progress is being made. We have published a Monograph on the Pliocene deposits of England, and two volumes of another on the Jurassic rocks, while a third volume is in the press. Another Monograph on the Cretaceous rocks is in preparation. Each monograph will embrace one system or group of rocks, and may consist of a number of volumes according to the importance of the system and the area which it occupies in the country.

In the preparation of the memoirs, and for museum purposes, much assistance is now derived from photography. Several members of the staff have become expert photographers, and a large number of views of geological sections, coast-cliffs, and other natural or artificial exposures of rock have been taken. These serve as illustrations for the Memoirs, and some of them are mounted to accompany the specimens in the museums.

Besides the geological Memoirs, the Survey has published a series of Decades of British organic remains, with plates and descriptions, also Monographs of important genera or groups of fossils, including Professor Huxley's essays on *Pterygotus*, the *Belemnitidæ*, the crocodiles of Elgin, and Mr. Newton's memoirs on Cretaceous fishes and Pliocene vertebrates.

VI. MUSEUM WORK.

For the complete illustration of the geology of a country it is necessary not only to construct geological maps and sections, and to publish printed descriptions, but also to collect and exhibit specimens of its minerals, rocks, and organic remains. Each branch of the Geological Survey has from the beginning kept in view the gathering of such specimens, and the galleries of the museums in London, Edinburgh, and

Dublin may be appealed to, as evidence of the manner in which the duty has been discharged.

The Museum in Jermyn Street is intended to be primarily illustrative of the minerals, rocks, and fossils of England and Wales, but as far as space will admit an endeavour is made to exhibit what is specially characteristic of the other two kingdoms. For the more detailed illustrations of Scottish geology recourse must be had to the Museum at Edinburgh, and for those of Irish geology to the Museum in Dublin.

The portions of the Jermyn Street Museum, more especially connected with the work of the Survey, are the collection of fossils, the series of rock-specimens, and the remarkably fine and complete suite of ores and their accompaniments from the mines of the British Isles and those of the Colonies. The Museum was organized to illustrate the practical applications of geology. As an example of the manner in which this design has been carried out, I may refer to the section in which the connexion between raw material and finished pottery is displayed. Our British ceramic collection was one of the earliest formed, and is still perhaps the most illustrative in the country.

The Fossils are arranged stratigraphically, and furnish the basis on which the Survey maps of the fossiliferous formations have been constructed. Every important subdivision of the Palæozoic, Secondary, and Tertiary systems is represented by a full series of its characteristic fossils gathered from the various districts in the British Isles wherein it is developed. These are arranged and tableted in such a way as to be readily accessible to the public. Those who wish to follow out the palæontological details of the Survey maps and memoirs, or to study general text-books of the science, have thus the fullest opportunities afforded to them.

The palæontologists with their assistants are continually engaged in arranging and retableting the collections to make room for fresh material received from the officers in the field, from donations or from purchase. Catalogues of the fossils in several departments have been prepared and published.

The Rock-collections have in recent years been greatly increased and entirely re-arranged so as to bring them abreast of modern petrography. That in the Jermyn Street Museum includes a collection of rock-forming minerals in illustration of the characters of the more important minerals that enter into the composition of rocks; a series of typical rocks, named, classified, and so arranged close to the eye that the visitor may have no difficulty in observing their general external characters; a section devoted to illustrations of various geological structures such as cleavage, jointing,

foliation, plication, the structures of igneous rocks, the effects of contact-metamorphism, the markings made by glacier ice, and the results of weathering in different rocks. But the chief part of the collection is a series of British rocks arranged in stratigraphical order from the oldest gneisses up to the most recent shell-sand. Not only are the sedimentary rocks represented in this series, but a large suite of igneous rocks is included, so that the student of volcanic history may see samples of the lavas and tuffs which have been ejected at each of the periods of volcanic activity in the geological annals of Britain. Diagrams and maps are placed near the specimens to show the geology of the districts from which the latter were taken. Illustrations are likewise given of the more important microscopic structures met with in rocks and especially among those of Britain. A handbook is being prepared to this part of the Museum which it is hoped may prove to be a useful aid to students of petrography.

The Geological Survey collections in the Museums in Edinburgh and Dublin are arranged on similar lines. They have been arranged stratigraphically to elucidate the maps, sections, and memoirs, and furnish a tolerably full series of specimens in illustration of the geology of each kingdom. A handbook for the Edinburgh gallery is published, and one for that of Dublin is nearly ready.

VII. GENERAL ADMINISTRATION.

I have already spoken of the organization of the staff. The collectors are placed under the direction of the field-officers. The assistant-geologists are promoted, as vacancies occur, to the ranks of the geologists. Over these officers come the district-surveyors, who supervise the work of a number of geologists or assistant-geologists in a wide district. The district-surveyors report to their director, who takes general charge of the work in his own kingdom. The Director-General is the head of the whole organization and is responsible for its conduct. He personally visits the officers in the field in each of the three countries, and is thus enabled to see that the work is being everywhere conducted on the same lines, and that the results obtained harmonize. It is his duty to bring the experience gained in one kingdom to the elucidation of difficulties met with in another, and to decide from time to time when the surveyors of one branch may usefully be sent to see the work in progress by another branch. It will be understood that to these duties in the field are added the general correspondence and administration of the whole service, and editorial labour connected with the issue of the various publications.

VIII. RELATIONS TO OTHER GOVERNMENT DEPARTMENTS AND THE PUBLIC.

From the beginning of its existence the Survey has been continually referred to by all branches of the Government service for information regarding questions in which a knowledge of geology is required. The sinking of wells, the choice of sites for forts and Government buildings, the placing of graveyards, the selection of materials for buildings or roads, the nature of soils and subsoils with reference to matters of drainage—these and many other subjects have been reported on. Nor has the general public been backward in application for similar information. The offices of the Survey are always open, and every assistance which can be rendered to enquirers is placed freely at their service.

The PRESIDENT said the work of the Geological Survey was one of special interest to mining engineers. As a body they had occasion very frequently to refer to their maps; and he had been struck with the accuracy with which the strata and faults were mapped out. Their thanks were due to Sir Archibald Geikie for having, as he might say, revealed the secrets of their work, and he had pleasure in proposing a hearty vote of thanks to him.

Prof. HULL said he was very pleased to be permitted to second the vote of thanks. Having been for forty years connected with the Geological Survey and employed upon it in England, Scotland, and Ireland, he appreciated the very complete outline Sir Archibald Geikie had given of its operations, which had recently been very largely extended. He would only take this opportunity of stating what, in his own opinion, was the work which the Survey was most urgently called upon to finish. Of course they all sympathized with Sir Archibald Geikie in his desire to make the Geological Survey of the country as complete as possible, both as regards the superficial deposits and the solid geology; but when they considered that there were numbers of large coal-fields at present only published on the 1 inch scale (which was of an entirely insufficient scale to allow of the proper representation of the geological details), he was pretty safe, in this company at any rate, in stating that the most important future work for the Survey was the re-survey, on the 6 inches scale, of the coal-fields which had not been surveyed on that scale. He had had experience of the surveying of coal-fields on both scales. He surveyed Leicestershire on the 1 inch scale, and he was perfectly aware that it required revision. It

was some thirty or thirty-five years since it was surveyed, and the now completed 6 inches Ordnance map would admit of its being undertaken on that scale immediately, if the officers of the Survey, the number of the staff, were sufficient to admit of it. Sir Archibald Geikie had stated that the 6 inches scale survey of the great South Wales coal-field had been commenced and was in progress; but was the number of gentlemen employed on that work anything like adequate to the amount of work to be done? He was very far from disparaging the work of superficial geology, for he was one of the first to commence it in Lancashire and Cheshire; but it seemed to him that it would be more to the benefit of mining enterprise in this country, if some of the staff engaged on that work were put upon the coal-fields in order that these might be re-surveyed and brought up to date on the 6 inches scale. He hoped this suggestion would be received as not in the least degree intended to criticize the work of the Survey, but for those in authority, for he was aware it was a matter for the Treasury to supply the means; the men were ready and the work would be undertaken, if the means were supplied for that important work.

The vote of thanks was cordially adopted.

Sir ARCHIBALD GEIKIE, in acknowledging the vote, thanked the members for the kind way in which they had listened to his paper. No one was more convinced than he of the desirability of revision, and no one would be more pleased to see all the coal-fields which were now drawn on the 1 inch re-surveyed on the 6 inches scale. It was not want of will on their part that had led to that work being delayed, but their staff was not large and there were certain definite pieces of work to finish. He might say that the question of the re-survey of the coal-fields must be determined by the Science and Art Department and the Treasury. The work of re-survey had been commenced in South Wales owing to a very strong memorial presented to the Science and Art Department, and he fancied that the same procedure must be followed as regards the other coal-fields.

Mr. F. G. SHAW then read the following paper on "Auriferous Conglomerates of the Witwatersrandt":—

AURIFEROUS CONGLOMERATES OF THE
WITWATERSRANDT.

By F. G. SHAW, Assoc. M. Inst. C.E.

In venturing to introduce certain theories as to the manner in which the auriferous conglomerates of the Witwatersrandt have been formed, and in which the gold (now found crystallized in the matrix of these conglomerates) has been deposited, the author hopes the members will grant him their indulgence should he not make his ideas sufficiently clear.

The auriferous conglomerates of the Witwatersrandt were first worked in 1887, near Johannesburg in the Transvaal, 280 miles from Delagoa Bay, 440 miles from Durban, and 1,013 miles from Cape Town. By the term "Witwatersrandt conglomerates," the author alludes to those in the basin or syncline now being worked and forming an isolated part of the extensive conglomerates which are common to the sandstones of South Africa. The basin has an east-and-west length of about 50 miles and a supposed breadth of about 40 miles. The east and west ends are very much dislocated and faulted. The dip of these conglomerates appear to be governed by masses of plutonic rock, which run parallel to the northern and southern outcrops, and have elevated the edges of the beds to angles varying from 12 degs. to 60 degs.

These seams, the author expects, will assume a horizontal position at comparatively short distances from the tilted outcrops, save where locally displaced by the intrusive masses of igneous rocks which are occasionally seen cropping out. Although no deep borings have proved the existence of these beds in the middle of the syncline, the continuity of their upturned edges and the regularity of their disposition, together with their known extent over South Africa, have impressed geologists with the conviction of their existence, and from 2,000 to 15,000 feet have been assumed as the probable depth reached by the lowest levels of this syncline.

The assumption is, that these beds of conglomerate exist over an area of nearly 2,000 square miles; the regularity of their width and character is well proved; and the gold up to the present time appears to be regularly distributed through the reefs. The importance of this field can be best understood by the output of gold which was for its sixth year, 1892, 1,210,868 ounces, a greater output than any other single field of similar

age in the world. During the first year of its history, 1887, this field produced 23,115 ounces, an amount equalled by the present weekly output.

The conglomerates of the high veldt of South Africa, the manner in which they were spread over so vast an extent of country, and the precipitation of gold in them combine to form a most interesting subject; but as the main reef seam at Johannesburg, with the attendant parallel seams, are the most interesting from their auriferous character, this paper will be to a certain extent confined to them.

Up to the present time, geologists and mining engineers have alluded to these conglomerates as being a sedimentary or sub-aqueous deposit and the gold, if they mention it at all, as being of an alluvial character and mechanically deposited. On this latter point Mr. C. J. Alford is perhaps one of the exceptions. In his book on *The Geological Features of the Transvaal*, he says, "it appears certain that the gold was not transported to its present position in the form of native gold by the action of the water;" and again he says, "its origin is a curious and interesting problem."

With reference to the conglomerates themselves, the terms "sedimentary" and "sub-aqueous" are both too indefinite, and the author prefers to assume that these conglomerates have been spread over the large surface in which they now exist and with the regularity which is one of their notable features, by a sea-beach action. The general assumption has been that they have been thus spread over the sandstones in which they are conformably interbedded by the action of rivers, or currents in the seas, at the bottom of which they are supposed to have been deposited: the author will briefly discuss these two theories.

While the action of rivers undoubtedly accounts to a great extent for the transportation and collection of pebbles, gravels, etc., in all parts of the world, no river action, that the writer has any knowledge of, could have so regularly spread over so large an area the seams of pebbles now forming these conglomerates. Even if these conglomerates existed only in the basin of the Witwatersrandt, a river at least 45 miles wide and of most peculiar character would have had to exist, which for a certain period would have had to deposit over its entire bed a uniform depth of pebbles, and then have had to deposit over the same extent a layer of sandstone for even a longer period, this action again being followed by the deposition of another layer of pebbles, then by another layer of sandstone, and so on, until these numberless layers of conglomerates, sandstones, etc., had been deposited. He knows of no analogous phenomena in any river-bed, and even were such phenomena known on a

small scale, he can conceive of no river whose bottom would be so regular and uniform as the sandstones on which these conglomerates lie, especially when the more violent action of rivers and currents in those days are considered.

These facts should dismiss the river-bed theory to the realm of improbability, and enable the writer to turn to the action of currents existing in a sea, by the aid of which pebbles brought to the edge would be spread evenly over an immense distance on its bottom. Such a regular layer of pebbles, which marine research has not yet discovered, would take a considerable number of years to form, and would have to be followed by a total cessation of pebble-deposit, a layer of sandstone-detritus taking its place and being deposited in the same ocean; these would then have to be followed in successive order by pebble and sandstone-deposits until the parallel seams now found had been formed. This view would necessitate a current in the ocean so regular in its strength and action as to carry these pebbles smoothly and evenly over the greater part of South Africa. No such current action is known at present in the ocean, the general tendency being to form banks and to heap up such coarse detritus as pebbles, instead of laying them evenly over the floor of the sea, and certainly no river flowing into an ocean would by its own action be able to spread its burden except in the vicinity of its mouth.

The writer cannot therefore accept either of these theories as being reasonable and common-sense explanations of the distribution of these conglomerates, and he prefers to assume a progressive sea-beach action, which gradually spread the pebbles brought down by the rivers, etc., from the probably, at that time, highlands of Central Africa, over the then low-lying ground of the South African continent.

In the science of geology, a thinker to be able to understand the difficult phenomena of the present must know the past, and from that knowledge he may be able to draw fair and common-sense views of existing phenomena, and thus knowing the present he may calculate as to the future. The failure of many men to grasp the theories of the present is due to their inability to take a retrospective view of the past: the only laws they know of, or will admit, are the laws governing the present period, and they assume that the quiet beat of every-day life on this staid and sober sphere has been the history of its past, not calculating on the turbulent energy of its youth, its bounding pulse and the restless energy of its younger days, or on its eventful change from a molten mass to its present state.

The author wishes therefore for a moment to go back to the time when our sphere was in a molten state, surrounded by an enormous thickness of atmosphere containing in suspension all the minerals, etc., whose point of evaporation was below that of the atmosphere, and gradually losing by radiation a portion of its heat. The formation of a film or crust would be the first real change on its surface, and as this crust became sufficiently thick to resist for some time the ebullition of the molten mass below it, the exterior portion would gradually become sufficiently cool to allow of the condensation of these various gases, minerals, etc. Many ages would pass during which gigantic igneous eruptions would take place, upsetting and distorting the existing rocks until at last the crust was continuous and strong enough to bear a certain superincumbent mass. As soon as the temperature would allow, seas would rest on this crust, eruptions would still take place and hydrothermal phenomena would still be common; but the land would gradually begin to be of a permanent character. The erupted rocks would harden into hills, etc., upheavals would remain permanent and depressions would become greater, and the early hydrothermal rocks would begin to appear, so that in course of time, low continents would exist as dry land, and the early sedimentary rocks, mudstones, shales, clays, etc., would be formed.

As South Africa is the continent to which our attention is drawn, it must be assumed that its existence at this period was such as has just been described, the sandstones being formed with their attendant conglomerates, etc., and lying horizontally a little above or below the then sea-level. These sandstones are found over the whole of South Africa in unbroken layers on the high veldt, with traces of their existence in and over the low veldt, and it may be assumed that the same phenomenon has been responsible for their existence, and that the land about the time of their creation was subjected to the same laws. These sandstones were undoubtedly deposited under sea-action and it must be assumed that the then elevation of the tongue of land of South Africa was very small, and that it probably existed as a low land lying to the south of the tropical parts of Africa, whose rivers would carry down the vast amount of pebbles, now spread over and amongst the sandstones, by the retreating action of the sea-beach belonging to the same ocean which deposited the sandstones.

The most generally-accepted theory is that the sandstones were formed at the bottom of the sea (which the few fossil-remains found in them confirm), and that the material forming the coal-measures have been formed by the tropical growth of vegetation. The operations of an advancing sea over such low-lying lands, fed as it would be by rivers

bringing down pebble-detritus, slowly creeping over the land, followed by long periods of total submersion, and succeeded by a retreating sea-beach action, would surely be accompanied with that of settling the light detritus brought into it, as a sandstone-deposit, and the spreading out on its edges of a uniform layer of pebbles (now turned into conglomerates by the subsequent infiltrating action of siliceous waters). In those places in which the inflowing rivers travelled through countries luxuriant with vegetable growth, bringing down in their waters an immense quantity of vegetable matter and gradually laying it down as a beach-line in the retreating course of the sea, making it (comparatively speaking) a level bed rich with vegetable seeds and with every facility for bringing forth the luxuriant growth from which coal-seams have been derived (until the return of the again advancing sea-beach line many thousands of years afterwards) during which time would be formed one of those non-continuous lenticular beds of various horizons, which would under the pressure of the superincumbent mass of sandstone be turned into the coal and shale seams now found.

The theory which might account for such an encroaching and retreating sea would probably be: gradual elevations of the land, followed by subsequent depressions, leaving the land at one time exposed to the air, and afterwards covered by the ocean. Mr. S. Herbert Cox in his excellent book on *Mines and Minerals* assumes this to have been the method by which the coal-seams and sandstones of Newcastle (New South Wales), were formed, and the theory is one easily understood and not at all difficult to accept, where the known alternate elevations and depressions of the land over vast continents are an accepted fact.

Whatever was the cause, South Africa has undoubtedly been alternately covered by sea-water and exposed to the atmosphere, and whether the land was alternately elevated and depressed, or otherwise, the sea must have come-and-gone and a sea-beach action been thus initiated. The appearance of the low veldt bears ample testimony to this fact, the mountain-ranges bordering the high veldt plateau of South Africa showing by their great denudation the erosive action of the advancing and retreating ocean, noticeably towards the De Kaap valley—the Makonga range being denuded of all its sandstones, and the overturned edges of its clays and quartzites, etc., on which the sandstones and conglomerates of the high veldt are elsewhere unconformably deposited alone remaining; thus indicating great aqueous action. Mr. C. J. Alford, in his geology of the Transvaal, alluding to this action says, "There is every indication that at one time a great rush of water cleared out the De Kaap valley and carried away to the eastward to the Indian Sea whatever deposit once overlaid it."

From a residence there of nearly a year, and a close study, the author is inclined to think that a succession of retreating waters had performed the work evidently done here, as well as elsewhere on the borders of this high plateau and this is what we might expect as a consequence of the theory he has advanced.

The next and most interesting point, is the manner in which the gold has been deposited in the conglomerates. The author has in his possession two pebbles taken from these conglomerates, which each contain a "colour" of metallic gold. These pebbles prove that from whatever source, and from whatever distance brought, some at least were gold-bearing; therefore, a certain amount of free gold would be mechanically deposited in these seams derived from the broken matrix of the more friable and smaller pebbles, by the grinding action of such a sea-beach as just described. Such a class of gold would be fairly well distributed and would present the rounded appearance of alluvial gold. Certain investigators at Johannesburg have microscopic slides showing such a class of alluvial gold; it may therefore be taken for granted, both by assumption and evidence, that a certain amount of the gold now in the conglomerates was mechanically deposited in the way just mentioned, through differing from ordinary alluvial deposits of gold in the manner in which it is spread through the conglomerates, in its extreme fineness, and by its not lying on the top or bottom of the seams, not having being carried there so much in the form of free gold, but deposited more or less *in situ* from the destruction of friable matrix.

The gold, however, which is thus accounted for, forms but a small proportion of that carried in the reef. Mr. Alford says in his work just quoted, that so far as he has noticed "the gold is almost invariably in a more or less crystalline form, the cube in its derived forms being more or less detectable." He has also observed it in "the cleavage-planes of the pyrites in the form of minute plates and scales," and he also says "it appears certain that the gold was not transported to its present position in the form of native gold by water," and again "its origin is a curious and interesting problem." The result of the author's investigations has been to confirm those of Mr. Alford, and led him to a careful study of this subject, and it was only after a diligent search that he became convinced that the character of the matrix now holding the pebbles together had altered since those pebbles were originally deposited, and that the siliceous matrix now in the conglomerates was pseudomorphic in character.

He is therefore inclined to believe that the original matrix, whether argillaceous, calcareous, felspathic etc., must have been displaced and a pseudomorphic matrix carrying gold, sulphur, iron, etc., has taken

its place, and his reasons for thinking so are as follows :—In the oxidized as well as the unoxidized portions of these conglomerates the pebbles are held apart by a distinctly crystalline matrix of silica. Now, in whatever manner these beds were spread over so large an area, it cannot be imagined that the pebbles themselves sank into a firm, jelly-like mass of silica and remained more or less suspended in it, even if oxide of silicon ever assumed so consistent and glutinous a character. It is probable that an after-crystallization of the matrix must have taken place, together with a deposition of its containing minerals, and may be accounted for in the following manner. After the gradual laying down of these conglomerates, etc., intrusion of igneous rocks took place, and the vast horizontal beds of sandstones, etc., were in some places broken up and tilted, as in the Witwatersrandt basin, and so acquiring a dip would either form natural drains for infiltrating surface-waters or funnels through which the underground thermal-waters, laden with their store of minerals, would force their way upward (through the fissures dislocating these seams and caused by the upward action of trappean rocks) and reach the surface. In either case the silicon contained in these waters would crystallize in its passage through the conglomerates, and form the matrix that contains the minerals now found. It can easily be understood that an argillaceous or other matrix would soon be eaten away by such an action, and so the succeeding matrix would become pseudomorphic in character. The contained minerals of such an infiltrated solution would even penetrate to some distance into the hanging and foot-wall of the containing sandstones, which, so far as the author can observe, it certainly seems to have done.

What then is the likelihood of such solutions containing gold? It is well known that gold is held in solution in salt-water at the present time, and probably much more existed in solution in the early days. Mr. Sonstadt has calculated that one ton of salt-water contains one grain, or about two pennyworth of gold. Taking Mr. John Murray's estimate of the quantity of salt-water on the earth, this will give an enormous mass of gold considerably over a cubic mile in bulk which was held in solution.* The infiltrating powers of such an overhead sea can be easily imagined, and a certain amount of this gold would be crystallized by chemical action

* Mr. John Murray estimates the volume of salt water on the earth to be equal to an envelope 2 miles deep, and taking the diameter of the earth at 8,000 miles, this volume will be $(8,000^2 \times 3.1416 \times 2 =)$ 402,124,800 cubic miles. If there be 1 grain of gold in each ton of water the ratio of the weight of the gold to the weight of the sea-water will be as 1 to 15,680,000; and the ratio of the bulk of the gold to the bulk of the sea-water (taking the weight of gold as being 20 times heavier than water) will be as 1 to 313,600,000. Therefore the volume of gold in the sea-water will be $(402,124,800 \text{ cubic miles} \div 313,600,000 =)$ 1.28 cubic miles.

and to a certain extent deposited in the reef. But even if the gold held in solution in salt-water has not been the active means of enriching these and other reefs (and the author certainly believes strongly in its being responsible for part of the gold found in them) it must be remembered that after the gradual deposition of these sandstone measures, which must have taken immense periods of geological time, this part of the earth's crust was gradually elevated, as the earth cooled and contracted, until marine invasion was a thing of the past. Then the continuous downfalls of rain and great geyser visitations would form shallow thermal seas containing large amounts of minerals in solution, and the tilted conglomerates would become natural drains, carrying the waters of these seas to the fissures (caused by the trappean eruptions) penetrating their systems and thence taking it to some subterranean cavity, perhaps to be thrown up again bearing more mineral. The result of these streams carrying as they would a large amount of silicon would be the eating away of the matrix and the crystallization of the silicon in its place, probably filling, at different parts of the conglomerates, the fissures caused by the intrusive action of the trappean rock.

If, on the other hand, the matrix and containing minerals were formed by the action of an upward flow from some thermal spring containing siliceous and other matters in solution, entering the conglomerates at points where the intrusive trappean rock had cut them off, then the remarkable affinity for gold which these trappean rocks seem to possess should be remembered. They are in this country frequently associated with gold, which they might communicate to, or take from, such thermal springs and by thus imparting the gold to the water in their vicinity, or only depriving it of the certain quantities of such gold, have allowed this gold or the residue of the gold to become crystallized in the siliceous matrix of the conglomerates, and thus deposited in a crystalline form in the reef.

If the author's theory as to the pseudomorphic character of the matrix of the Witwatersrandt reefs be correct, it is also probable that reefs will be found of considerable value and extent in the vicinity of the intrusive dykes, which have broken through the sandstones; and his theory will certainly warrant a greater faith in the continuity of gold in these reefs than when it was thought to be of an alluvial character and mechanically deposited. In the latter case it would like all alluvial deposits become uncertain and erratic; while in the former case it would be identical with the matrix holding the pebbles together in all parts of the auriferous conglomerate.

Mr. EDWARD HALSE (London) said they were all very much indebted to Mr. Shaw for his very interesting paper, and he hoped he might be allowed to remark that such papers were of especial value because they promoted discussion. With regard to the supposed fluviatile origin of the Transvaal bankets, are not certain large rivers constantly changing their beds, and is not this especially the case in a river-valley having a small fall? The old bed of some of the larger rivers in South America, for instance, can be traced for a good many miles on either side of their present bed. It may interest members to know that an auriferous conglomerate-deposit is now being formed along the bottom of the Ancobra river which runs into the sea a little north of Axim, on the West Coast of Africa. Here divers have proved that the present bottom in places is composed of several feet thick of a very compact mixture of small pebbles, broken quartz, and white sand, below which are large pebbles buried in auriferous whitish clay.* He (Mr. Halse) was not advocating a river theory for the origin of banket-formations in general, but was merely showing that it was not impossible. Some probably have been built up at the bottom of an inland lake, lagoon, or sea, or possibly at or near its margin by some sort of sea-beach action. It was very questionable whether enough was yet known about the South African bankets to say how they were laid down. According to one geologist† the beds have been subjected to great lateral pressure, folds and repetitions are very frequent; the matrix shows evidence of having been squeezed round the pebbles, and exhibits a schistose structure, the pebbles themselves are very much broken, and moreover the whole of the beds have been thrust into their present position over the older strata below them. With regard to the uniformity of the conglomerates, as a matter of fact he believed that they were not of uniform thickness, they sometimes wedged out entirely, and in certain of them the pebbles were of a much larger size than in others. If the gold had come from sea-water containing it in solution, as suggested, would it not be reasonable to expect all the conglomerates of this area to be auriferous? but in point of fact some of them contain little or no gold. About two years ago, he (Mr. Halse) had an opportunity of examining and working banket deposits on the Gold Coast of West Africa.‡ They seem to throw some light on those of the Transvaal, although they are probably of much more recent age. They consisted of layers of talcose and titaniferous iron-sandstone, alternating with true conglomerate beds, also showing talc and iron-sand. The whole seam was auriferous,

* *Trans. Fed. Inst.*, vol. ii., page 83. † *Quart. Journ. Geol. Soc.*, vol. xlviii., pages 404-435. ‡ *Trans. Fed. Inst.*, vol. ii., pages 69-84.

but the gold increased in richness towards the floor of the deposit, the bottom layer consisting either of highly titaniferous iron-sandstone rich in alluvial gold, or of rich banket. In the latter, as in the Transvaal, the gold rarely occurred in the pebbles, but was found in the cementing material or matrix, and was often collected round the pebbles. The gold was mostly water-worn and in fine plates or grains, distinct crystals being rare. A large proportion of it too, as in South Africa, occurs in an exceedingly fine state of division. The bankets of the West Coast of Africa exhibit little or no metamorphism, faults are rare, and, although the beds dip at an angle of from 30 degs. to nearly vertical, no volcanic rocks occur in the immediate vicinity to account for this tilting. The cementing-material was always siliceous and generally of very loose texture, crumbling readily in the hand, although in some parts a very hard banket is found, probably as hard as anything occurring in the Transvaal. He (Mr. Halse) would suggest that the South African bankets were once true alluvial conglomerates similar to those of the Gold Coast, and after consolidation and upheaval they were subjected to great and long-continued metamorphism. Being of a porous nature, and more or less steeply inclined, they were subject to the same influences—chemical and other—as have helped to form the present structure of a true fissure-vein. A large portion of the alluvial gold, together with the associated iron-sand, were, it is suggested, dissolved and were subsequently crystallized out as auriferous iron pyrites and free gold. In addition a re-arrangement of the gold contents appears to have resulted from the leaching action, as the ore in some of the bankets has been found to occur in distinct shoots. Iron pyrites exists in the diorites of the district, and, by some, these rocks have been regarded as the source of the iron pyrites in the conglomerates. The bankets have probably been enriched by their means, but it is very questionable whether the whole or even the greater portion of the auriferous iron pyrites has come from that source.

Mr. WALCOT GIBSON (London) pointed out that if the beds ever assumed a horizontal position within so short a distance of their outcrop, as stated by Mr. Shaw, it would greatly increase the value of deep-level properties, while those situated on the outcrop would ultimately lose their reefs. But it was certain that the beds never assumed a horizontal position, as the southernmost reefs always possess a dip not much less than 15 degs. to the south. The parallelism of the beds as represented by Mr. Shaw as occurring at the Ginsberg mine was misleading. The beds on the Randt, taken collectively, were really lenticular in character, as could easily be seen, as the beds are traced east and west of

Johannesburg. The country rock, as well as the conglomerates, contained iron pyrites; but the gold was chiefly restricted to the conglomerates, though the pyrites of the country rock, judging from assays, contained a small percentage of gold. The age and origin of the conglomerates was uncertain, and Mr. Shaw produced no evidence of their being of marine origin. The connexion of the gold-bearing conglomerates and the igneous rocks was not settled. The richness of the reefs seemed to have no connexion with their proximity to the igneous masses or dykes. The tilting and dislocating of the strata was prior to the igneous intrusions. The future prosperity of the Witwatersrandt gold-fields was fully established, and was independent of any theories which may be proposed to account for the origin of the gold or of the conglomerates.

Mr. S. H. Cox (London) said he considered Mr. Shaw's paper to be a very interesting and important one. The paper seemed to cover such a lot of ground, commencing with the earliest period of geological history to the present time, that to attempt to discuss it would be impossible. He scarcely agreed with Mr. Shaw's contention that a river could not deposit conglomerates such as those described. He knew of places—the Canterbury plains for instance, in New Zealand, about 90 miles long and 50 wide, shingly plains deposited by the rivers. Mr. Shaw's statement as to the source of the gold rather appealed to him as likely to be correct in some cases. He did not believe that the infiltration of sea-water had deposited gold, for if it had been able to deposit gold at all the deposition would have been world-wide, and wherever they had marine conglomerates they would get deposits of gold. But he thought Mr. Shaw had pointed out that infiltration of waters charged with gold had to a certain extent altered the matrix of the conglomerates, and, in altering it, had met with something to precipitate the gold, and from that point of view he thought Mr. Shaw had certainly given them something new. He might mention that in New South Wales there was a deposit known as the Junction Reefs at Belubula, where in about 90 feet of strata there were 50 feet of auriferous material alternating with slates. The thickest of the auriferous beds being 18 feet and the thinnest 2 or 3 feet; and these gave $\frac{1}{2}$ ounce of gold to the ton in crushing; the beds consisted of sand, they were not conglomeratic in any form but were impregnated with free-gold and interstratified with beds of slate. If one attempted to go into the theories of past times he took rather a different view from Mr. Shaw, who thought they would require an accurate knowledge of the past to know the present; for he thought they should have an accurate knowledge of the present to know the past.

Mr. G. J. BINNS (Netherseal) said Mr. Cox, in the last portion of his remarks, had anticipated what he was going to say; he was sorry for it, but he would cap his observations by a quotation. Sir A. Geikie in one of his books says "that the present affords a key with which to unlock the secrets of the past." Perhaps everybody present except Mr. Shaw would acknowledge that, and that if they were to abstain from drawing conclusions in geology until the Survey had finished, what might be called the pre-pre-pre-Cambrian rocks of the Western Highlands of Scotland, they would have to wait a long time.

Mr. D. A. LOUIS (London) said that judging simply from a study of the characters of the conglomerate rocks, as exhibited in samples to which he had had access, it seemed highly probable that they should be of river-formation; he did not think it possible that they could have been formed in the sea, without including some fossils indicative of such an origin. What had been said by Mr. Halse and Mr. Cox in reference to extensive shingly deposits formed by rivers was also evidenced in the vicinity of the upper reaches of the Missouri river in America. There, vast beds of auriferous and ferruginous gravels are found deposited on the bed-rock, and above them huge deposits of river sand, varying from 50 to 100 feet in thickness, and above that again beds carrying gold are sometimes encountered. These deposits are quite loose at or near the surface, but lower down are frequently conglomerated, but are in no way metamorphosed. There, however, appears to be no lack of existing proof of the fact that rivers are or have been capable of covering extensive areas with gravel-deposits. Specimens of Transvaal conglomerates in his (Mr. Louis') possession vary in character from masses of very coarse gravel and fine sand loosely cemented together, with each grain visible up to masses very closely resembling in character solid quartzite in which even the larger pebbles are scarcely discernible, indicating that these deposits have undergone varying degrees of metamorphism. In the less metamorphosed specimens, the gold is generally found in the cementing or fine material surrounding the larger pebbles, and is associated with pyrites; and this under the microscope appears generally in small rounded grains and but rarely in well-defined crystals. Inasmuch as the reader of the paper, like others who have seen much of these conglomerates, admits that the pebbles sometimes contain gold and pyrites, thus proving the existence of these substances in the original rocks, and, moreover, as a deposit of coarse pebbles like those met with in these conglomerates would provide most favourable conditions for the settlement and concentration of small grains of heavy material brought down by the

river, it seems feasible that these minerals might have come from the same rocks as the pebbles or some other ancient auriferous strata. The specimens examined by the speaker did not present the usual characteristics of minerals, complex, deposited from infiltrating solutions, although, of course, any liquid or solution, auriferous or otherwise, would necessarily trickle through such a deposit, and the passage of a simple siliceous or calcareous solution would be sufficient to account for the cementation. The subsequent metamorphosing and tilting and other such agencies might account for the fine condition in which most of the gold was found; and with reference to the crystalline character of the gold, some of the gold from the Missouri river deposit, previously alluded to, was, under the microscope, crystalline, although water-worn, and therefore not sharply crystalline.

Mr. FILBY (London) said the quantity of gold contained in the sea was estimated at a cubic mile. This was a curiously definite statement, and it would be interesting to know how the calculation had been made. The paper gave evidence of Mr. Shaw's deep attention to the subject, and he was sure they all appreciated his ability.

Mr. HENRY LOUIS (Singapore) wrote that he must, in the first instance, draw attention to the fact that Mr. Shaw is decidedly misrepresenting the views of mining engineers who have previously studied the banket beds of the Witwatersrandt, and that he was in error in stating that they had, up to the present, represented the gold in them as being "of an alluvial character and mechanically deposited." The true facts of the case were exactly the opposite. The first information about the geological characters of this district is contained in a few brief notes communicated by himself (Mr. Louis) to the *Mining Journal*, and published in that paper on November 13th, 1886*. In this communication he (Mr. Louis) distinctly stated that he had found the gold to be partly contained in the cementing-material of the banket, and that it was of a highly micro-crystalline character, and he further suggested that it might have been deposited *in situ* subsequently to the formation of the beds by the infiltration of gold in solution. So far as he knew this opinion had never been controverted since that time, but had, on the other hand, been corroborated by numerous independent writers on the subject, so that the theory now put forward by Mr. Shaw was in reality first promulgated by himself (Mr. Louis) seven years ago, or a year before these conglomerates were worked, according to Mr. Shaw. Of course, at the time when he wrote those notes, very little work had been done on the banket beds and that only of a most superficial nature, but the results of subsequent

* Page 1325.

explorations had only tended to confirm and amplify the general broad theories then put forward, however much it may have modified their details. No one, so far as he (Mr. Louis) knew, had seriously suggested the opinion which Mr. Shaw here tilts against, viz., that these beds were originally river-gravels. He looked upon them as marine beds: this may be so, but he (Mr. Louis) preferred his original theory—also propounded in the above notes in the *Mining Journal*—to the effect that they were of lacustrine origin. He (Mr. Louis) based this view upon the absence of fossils, such as would be expected in marine beds, upon the comparatively limited area which they occupy, and upon their general character. Mr. W. Gibson's view that the coal-beds above them are of lacustrine origin, may be held to support this view to some extent. He (Mr. Louis) believed that the area now occupied by these beds was once an inland lake into which mountain streams emptied themselves—descending from a range consisting largely of quartzites and quartz, some of which were auriferous, the lake-bottom meanwhile undergoing marked oscillations of level. He thought it possible that the mountain-range in question may have occupied the site of the Drakensberg range, the strata of which are distinctly older than and unconformable under the blanket-beds. Assuming this to have been previous to the date of the deposition of these blanket-conglomerates, the entire theory looks very plausible, as the known formations of the Drakensberg with its auriferous formations might well furnish the quartzose pebbles of the blanket. Of course he (Mr. Louis) might be wrong in the above assumption as to the date of upheaval of this range; if so, some other mountain-chain must have existed, the degradation of which furnished the pebbles. So little is known definitely of the geology of South Africa that all theories must be more or less tentative. The pebbles are so thoroughly rounded and so comparatively uniform in size that they must evidently have travelled long distances, and probably by rapid mountain streams before being deposited in this inland lake, where they alternated with layers of sand, the beds of gravel thinning out here and there and discontinuing in places to reappear again in others, oscillations of the level of the lake-bottom accounting probably for these alternations of gravel and sand, whilst ultimately a further rise may have produced the conditions which have resulted in the formation of the coal-deposits. The upheaval of these gravels and sands and their subsequent more or less complete consolidation has produced the blanket beds as at present found with their intercalated beds of sandstone, forming a trough synclinal in general aspect. Mr. Gibson has, however, pointed out, and has fairly well established his case (although the evidence adduced by him has been

ignored by Mr. Shaw), that this is not a simple basin but that these strata show excessive faulting, reversed faulting, dislocation and folding, and all the other phenomena attending the disruption of strata by violent volcanic action. The cementing-material which binds the pebbles together is mainly siliceous; it also carries mica and much iron pyrites, although the latter has been completely decomposed down to very considerable depths. This cement also contains finely-divided, highly crystalline gold disseminated through it. Some of the pebbles, moreover, are themselves auriferous. The deposition of the gold was effected after the formation of the beds and probably after their partial consolidation and uptilting. The evidence in proof of this statement is the highly crystalline nature of most of the gold, the very small proportion of water-worn gold, the fineness, the uniform distribution throughout the beds of conglomerate, and the absence of nuggets. Had the gold been deposited simultaneously with these thoroughly rounded pebbles and by the same agencies, it would all have been in well-rounded water-worn grains, varying in size from flour gold to nuggets, and would have been most abundant in the bottom layers of the conglomerate. Instead of this we find the gold in very sharp-edged crystals, finely divided, and evenly disseminated throughout each bed of banket. He (Mr. Louis) held that the banket beds were percolated, after their upheaval, by subterranean waters carrying in solution gold and iron pyrites, or a substance capable of producing the latter. In a paper read recently before the Mineralogical Society, he (Mr. Louis) ventured to propound a theory to the effect that the solvent of gold in nature had been alkaline and not acid as generally supposed, and this view would accord well with the siliceous character of the cement binding the pebbles together. In fact the deposition of pyrites and gold may be looked upon as a stage of the metamorphism which has transformed the layers of loose gravel into the conglomerates of to-day. Of course the solution, which could percolate readily through the conglomerate-beds, would also find its way to some extent through the denser sandstones; hence we should expect to find, and we do find, that these sandstones are slightly auriferous in the neighbourhood of the banket-beds. The deposition of the gold from its solution was determined, either by the chemical action of the iron pyrites, or was caused by the same reducing action which produced the latter mineral. Either theory will account for the fact that so large a proportion of gold is free even at great depths, where iron pyrites forms a considerable proportion of the cementing-material. A similar action has no doubt produced the crystalline gold of the Devil's Kantoor and some parts of the Pilgrim's

Rest district, which also owes its origin to chemical action, and is not alluvial, although sometimes spoken of by that term. It is possible, though by no means yet proved, that this gold was formed simultaneously with and by the same agencies as the gold in the banket-beds. He (Mr. Louis) might briefly recapitulate his ultimate views as to these banket beds as follows:—That the banket series of the Witwatersrandt forms an irregular, much faulted, trough of alternating sandstones and conglomerates which were originally of lacustrine origin, and had been uptilted through violent eruptive action to their present steep angles of dip; that the gold contained in these deposits is partly in the pebbles themselves, to a very small extent is water-worn gold contemporaneously deposited, but it is principally crystalline gold occurring in the cementing-material, deposited by chemical action in the interstices between the pebbles of the banket, after the upheaval and partial consolidation of the latter.

Mr. F. G. SHAW stated that he was, however, very pleased to observe the general acceptance of the two theories by Mr. Halse and by Mr. Cox, and could only hope that they would be enabled to visit South Africa, as he felt convinced they would then be able to concur fully in his theory. He (Mr. Shaw) thought that from whatever source the gold came, it would not be likely to be deposited evenly in all places; where it encountered chemicals likely to crystallize it from solution, it would there be deposited. The precipitation of gold from salt water would depend on the mineral filling the veins, or in their vicinity, through which it percolated. Although the existence of gold in the conglomerates on the Gold Coast of West Africa was an interesting fact, this region was so distant from the Witwatersrandt district, and of so entirely a different geological character that a comparison could hardly be made, especially as Mr. Halse admitted their much more recent age. He (Mr. Shaw) had clearly pointed out in his paper, that many conglomerate formations were due to river action, and that nearly every alluvial gold-field had been thus created; but the remarkable parallelism, uniformity of thickness, evenness of footwall, and extent of the Witwatersrandt beds precluded the idea of their formation being due to river action. Had Mr. Halse visited the Witwatersrandt gold-fields, he would undoubtedly be the first to admit that neither river action nor that of currents at the bottom of the ocean would satisfactorily account for the spreading of these conglomerates so evenly and with such a perfect footwall over so large an area. Mr. Halse had endeavoured to show that the matrix of the conglomerates was due to metamorphic and not to pseudomorphic action; but he (Mr. Shaw) pointed out that this was not at all probable; the smallest pebbles showed no sign of metamorphic action, and, as the peb-

bles and the matrix were of the same mineral, what altered one would affect the other. Mr. Binns' inability to understand the meaning of the simile advanced in the paper, that "a thinker to be able to understand the difficult phenomena of the present must know the past," could be best met by the following quotation from Sir Charles Lyell:—"It would be endless to attempt to reply to all objections urged against those who would represent the course of nature at its earliest periods, as resembling in all essential circumstances the state of things now established"* and the words of Sir A. Geikie's quotation, just quoted by Mr. Binns, "that the present affords a key with which to unlock the secrets of the past," and with the knowledge so obtained to explore the mysteries of the present and acquire the treasures now hidden. He (Mr. Shaw) stated in his paper that "these seams, the author expects, will assume a horizontal position at comparatively short distances from the tilted outcrops" which is undoubtedly proved by comparing the dip of the reefs at their outcrop with the records of the dip at the deep-level boreholes. In stating that it was certain "that the beds never assumed a horizontal position," Mr. Gibson spoke without the slightest evidence to corroborate his assertion; and he was entirely mistaken when he said, "that the southernmost reefs always possess a dip not much less than 15 degs. He (Mr. Shaw) had surveyed the Meyer and Lebe gold-mine, and found that the southernmost reefs (only 4 miles from the main reef) had a constant dip of 5 degs., and that the whole of the black reef series was equally flat even at its northern edge. It was incorrect to say that the section of the Ginsberg mine was misleading, as the drawing was an exact section of the reef as it existed. He (Mr. Shaw) did not state that the conglomerates were of marine origin, and considers that Mr. Gibson should confine himself to a criticism of such statements as he (the author) had advanced in his paper. What he said was that the pebbles, etc., brought down by rivers, were spread by the action of a receding or advancing sea-beach. The auriferous reefs have not been yet followed down to the igneous rocks, and Mr. Gibson has no right to assume that the gold in the reef is unconnected with trap rocks. He (Mr. Shaw), referring to the supposition that faults had been the means of throwing the seams of conglomerate towards the surface, contended that the evidence of the various boreholes proved that the seams were absolutely dipping at a less angle, instead of being tilted at a greater angle, as they would have been if they had been thrown up by faults, and he thought it would be preferable for the reefs to assume a less dip than to be cut off by a fault. He (Mr. Shaw) was surprised at the tone of Mr. Henry Louis' remarks which

* *Principles of Geology*, page 511.

did not allow him to be right in any instance and attached theories to him which he had not advanced, and yet endeavoured to claim his (Mr. Shaw's) theories, the originality of which had not otherwise been questioned. As to his (Mr. Shaw's) tilting against the theory of conglomerate beds being originally river-gravels, his paper did not even suggest that they had been so deposited. Mr. Louis claims to have advanced statements in a November number of the *Mining Journal* of 1886*, which he says have never been controverted, that the conglomerates of the Witwatersrandt had been formed by streams depositing in a lake the detritus derived from surrounding mountains. On this point he is one of those who have advanced the usually accepted theory for the formation of all conglomerates, namely, that of a sedimentary or subaqueous origin. He (Mr. Shaw) considered this to be (in the case of these conglomerates) a too general term—as both these words have a wide and not a precise enough meaning—and he therefore advanced the theory of a retreating or advancing sea-beach action as being more definite. As regards this theory, he (Mr. Shaw) was very pleased to find that Prof. A. H. Green, who had arrived at the same conclusion regarding the Dwyka conglomerates of the Cape Colony, says in his *Geology and Physical Geography of Cape Colony*, with reference to the Dwyka conglomerates, “the notion I formed as to the origin of this rock was that it was a coarse shingle formed along a receding coast line.”† This he (Mr. Shaw) considered coming from so high an authority as confirming the views he separately formed as to the formation of the Witwatersrandt conglomerates which, as he had stated, show most clearly how unsatisfactory a river or lake action theory is in accounting for their present appearance. His (Mr. Shaw's) statements on this point are not therefore inaccurate, nor do they misrepresent the views of mining engineers but are corroborated by his (Mr. Louis) evidence. No mountains exist or have existed near these conglomerate beds, and no lake action would account for the spreading of these conglomerate beds over South Africa, and for alternately laying the parallel beds of sandstones and conglomerates as they now exist. Crystalline gold was found and recognized almost from the first in these conglomerate beds by most mining engineers, and he (Mr. Shaw) had quoted Mr. Alford's remarks on the subject in his paper. He certainly was not aware that Mr. Louis had written on this question, as appears to be the case, in the short communication which he addressed to the *Mining Journal* in 1886. Mr. Louis' words in this letter were :—“ Or whether their auriferous contents are not due to the deposition of gold *in situ*, subsequently to the formation of the deposits, owing to the infiltration of gold in solution from the surface.”

* Page 1325.

† *Quarterly Journal Geolog. Soc.*, vol. xliv., page 243.

Surely Mr. Louis does not claim this to be, at that time, a new idea, or one calculated to excite any surmise or comment ; he supposed if any one had wished to controvert such a widely accepted and well-known theory they would have started at least in the days of Agricola, who wrote in the sixteenth century regarding the minerals found in veins, which he considers had resulted from precipitation from aqueous solutions filtering through veins, to say nothing of having to deal with Werner who wrote in the year 1791, and proved the deposition theory from overhead solutions. Yet Mr. Louis in his small and by no means original communication claims to have advanced views which he had not since seen any reason to seriously modify, namely, that conglomerate beds have been formed by river and lake action, and that crystalline gold has been deposited from solutions as in the case of these conglomerate beds. Mr. Louis controverted his (Mr. Shaw's) statement, that the history of this field commenced with 1887 ; what he said was, that in the first year of its (crushing) history, this field produced 23,115 ounces of gold, and no practical mining engineer would have misunderstood his statement. He might remind Mr. Louis that the views he had advanced, and on which the interest of the paper centred, related to the origin and mode of consolidation of the conglomerate beds in their present form, bringing forward (firstly) a sea-beach and sea action to account for the spreading of the alternate layers of conglomerates and sandstones (a portion of his (Mr. Shaw's) paper which has not, so far, been upset, or seriously attacked) ; and (secondly) the pseudomorphic character of the matrix to satisfactorily account for the comparatively simultaneous crystallization of the silica, sulphides, and gold. The real difficulty with scientific observers has been the apparently wonderful manner in which these minerals are associated and combined together in a sedimentary deposit, and no difficulty could have been experienced in determining how the gold and sulphides found in a crystalline state were deposited. Mr. Louis had certainly not been able to disprove the originality of the ideas advanced in his (Mr. Shaw's) paper, to which he was led by the "mechanical deposits of the conglomerates having been altered into the characteristics of an ordinary fissure vein," as pointed out in *Engineering* of June 9th, 1893.*

The PRESIDENT proposed a vote of thanks to Mr. Shaw for his paper.

Mr. W. F. HOWARD (Chesterfield) had pleasure in seconding the President's proposal.

Mr. SHAW acknowledged the vote.

Mr. SPENCER read the following communication on "The Support of Buildings" :—

THE SUPPORT OF BUILDINGS.

BY W. SPENCER.

Probably nothing connected with mining has given rise to so much litigation as the question of damage to buildings on the surface by underground workings and, so far as the writer knows, the subject has not hitherto been brought before any mining institute. In undertaking to read a short paper on this subject the writer thought that it would at least form a nucleus for additional facts, which would probably be added by other members, and that ultimately a large amount of valuable information would be recorded in the *Transactions*. The writer wishes at the outset to state that he, from the first, contemplated obtaining information from friends in different parts of the country ; but he did not fully realize the hesitation that might be felt in some cases in giving such information from fear of possible legal proceedings, even although the name of the person and the locality might be withheld. For this reason the cases recorded are fewer than he expected to be able to give.

No doubt many people have been struck in travelling through different parts of the country with the number of buildings of different kinds which they have seen cracked, more or less, in localities where it was quite certain that no underground operations had ever been carried on. If similar effects are observed in districts where mineral is being worked, such damage is, as all are unpleasantly aware, immediately attributed to such workings.

The first examples of subsidence are taken of cases occurring in Leicestershire, and a section of the strata in that county is given in Appendices B and C. The measures rise to the west, about 1 in 14. The surface is almost level over the areas referred to. In this district the coal is entirely taken away and the roads are made through the gob ; if any coal is left for the support of buildings, it is left as a solid block, and not in the form of pillars, as in other districts.

Fig. 1, Plate VII., shows the position of a number of houses, under varied circumstances, none of which are damaged, with one single exception (A). The circumstance is remarkable, seeing that some of these

houses are in positions in which it is generally considered that injury is most likely to occur, *i.e.*, partly on solid coal and partly on the gob. The only building damaged (A), and that not to a great extent, is standing on whole coal. It is a house of two storeys high, with a large attic running the length of the house. No coal had been worked within about 90 feet of it, except on one side only. The contention of the owner was that it had been damaged in consequence of the underground workings, and a claim for compensation was made. On the contrary, the lessees of the colliery contended that the damage was due to the withdrawal of water from the foundations, which were built upon a gravel bed. This contention was supported by the fact that a cottage on a similar foundation and also a large farmhouse, of similar construction to the first-named, cracked simultaneously with it, although the latter were too far away to be affected by underground workings, the last-named farmhouse being about two miles distant. It was thought that there was a good defence, but having in view "the glorious uncertainty of the law" on the one hand and the certainty of expense either at law or of arbitration on the other, the matter was settled by the lessees paying the greater part of the amount claimed.

As a general rule, the greater the height and weight of a building, the greater the likelihood of its being damaged, although a case is recorded where a thick seam was worked within 60 feet of a large and high building without damage, while a small house near was considerably injured.

As proving the effect of the withdrawal of water, a house, from under which the whole of a thick coal-seam had been removed, was entirely uninjured until, owing to underground workings many hundreds of feet away, the well was drained, and the house immediately cracked.

The preceding cases, Fig. 1, and those shown in Figs. 2, 3, and 4, Plate VII., show a very marked contrast to each other, under circumstances, so far as known, precisely similar in every respect; in one set of cases no damage was done, while in the other the houses were damaged to a considerable extent, although at no time rendered uninhabitable. The buildings shown in Figs. 2, 3, and 4 are a little more than a mile from those shown in Fig. 1, nearly on the water-level line of the Coal-measures, and on a level surface.

The following cases occurred in the county of Durham, and were kindly given to the writer by his friend, Mr. Thomas Douglas, of Darlington. See Figs. 5 to 16, Plate VII., and Appendix A.

In another case, the Main Coal seam wastes lying at a depth of 150 feet were filled with water. The Harvey seam at a depth of 420 feet and the Brockwell seam at 660 feet were worked out below for an area of about 20 acres, and no water came down.

One of the most eminent mining engineers in the North of England prescribed the following conditions to secure the support of an important railway viaduct*:—A width of 60 feet of solid coal shall be left on every side, and a further width of 33 feet of pillars containing 60 per cent. of the whole coal.

In another case where the coal, $3\frac{1}{2}$ feet thick at a depth of 540 feet, was found about level—60 feet of solid coal were left from the centre of the river Wear, and a further width of 132 feet was left in pillars.

In another case all the coal was taken out beyond a distance of 96 feet from a large house, and pillars containing 64 per cent. of the whole coal were left under the house without damage being done. The depth of the coal-seam was 480 feet, about $3\frac{1}{2}$ feet thick, and lying nearly level.

For the support of a church there were left on each side respectively 75 feet, 90 feet, 99 feet, and 135 feet of solid coal. The depth to the coal-seam, $3\frac{1}{2}$ feet thick, was 420 feet, the strata being nearly level.

The manager of a colliery in Chili informed the writer that the waves of the sea could be heard in the workings. The coal-seam was about 6 feet thick, and was dipping rather rapidly under the sea.

My friend, Mr. A. L. Stcavenson, of Durham, writes that—

"He found the injury from a goaf depended: (a) on the depth, (b) on the thickness of the seam, and (c) very largely upon the nature of the surface, whether rocks or clay, or sand with water. Then we have to consider the support derived from adjoining strata if the country is level. In Durham, as you know, we have the wash or drift, which makes a very uncertain foundation. My house is 480 feet above the Brockwell coal-seam, 3 feet thick, with 40 feet of clay—this made any calculation doubtful, but I left as a support a width equal to half the depth, or 240 feet, and worked round three sides of it, the result being that the building has moved rather than cracked, and doors have required to be cut and re-hung; there is no important injury, and the well from which we get drinking water is not affected."

"At the Skelton mines in Cleveland, at a depth of 240 feet with 20 or 30 feet of clay, we have taken out 10 feet of ironstone. The agent's house, 750 feet distant, is badly cracked, the whole hillside seems to have slidden away (the rocks being the mild shales of the district). On the other hand, with the strong rocks in Durham and a house standing on freestone, I have taken out all the coal, $4\frac{1}{2}$ feet thick, at a depth of 600 feet within 66 feet of a farmhouse and outbuildings, without damage being done (Fig. 17, Plate VII.). Twenty years ago, damages were paid for a house in Bishop Auckland: the coal was $4\frac{1}{2}$ feet thick, lying at a depth of 720 feet, and the workings came within 132 feet of the house. I believe this did not really do the damage, which was caused, I think, by the water being withdrawn from a

* The coal-seam, $3\frac{1}{2}$ feet thick, at a depth of 510 feet was lying nearly level.

sandbed by the town-drains. The case went to the Assizes and the jury gave a verdict against the colliery owner. Water in sandstone is a frequent cause of damage to houses, and at law (if it can be proved that it is owing to the withdrawal of the water) the colliery owner is not liable."

"I should say that at and over 500 feet in depth, with good rock only to deal with, there is very little fear of the removal of any seam in the county of Durham doing much damage."

The writer was present at the arbitration in the case of "*Bonomi versus Backhouse*," which has often been referred to as a test case, and the following is an extract from a report which appeared in the *Colliery Guardian* of August 24th, 1861:—

"The house was shown to have been erected above forty years, that the colliery lessees had worked the coal-mines under, and contiguous to, the plaintiff's property in the usual manner, viz., by taking away a portion of the coal and leaving the residue standing as pillars to support the roof of the mine. The pillars so left were proved to be quite sufficient for the support of the superincumbent strata if all other portions of the mine had been worked in a similar manner, but in the course of their workings the defendants in the year 1848, worked the coal from $4\frac{1}{2}$ acres, purchased of a Mr. Simpson, leaving pillars, and in the following year removed the pillars from about two acres. As soon as these pillars were removed, the roof of the mine which they supported fell in, and produced a goaf, called Simpson's goaf. As this increased the pressure on the adjoining pillars, there was produced what is known amongst miners as a "thrust," the natural effect of which was to crush and knock down the pillars in the vicinity of Simpson's goaf, and as the thrust gradually extended the roof of the mine fell in, the strata above were disturbed, and the buildings on the surface, including a great part of West Auckland, were cracked and injured. In the year 1854, the thrust in its injurious consequences began to operate on the plaintiff's premises, which were distant over 380 yards from the point where the pillars were first removed under Simpson's land. The pillars supporting the roof in this portion of the mine were in turn thrown down, and consequently the foundations of the plaintiff were disturbed and subsided in such manner as in December, 1854, to cause a portion of the damage complained of. In 1856, the premises were still further damaged, and on May 20th in that year the plaintiff brought this action. The arbitration further found that the working of the pillars under Simpson's land was the sole cause of the damage complained of by the plaintiff. On these facts being found, the case was first argued before the Court of the Queen's Bench, and it was contended by the counsel for the defendant, the present Mr. Justice Hill, that the plaintiff's right to recover damages was barred by the Statute of Limitations, which limits the time for bringing an action, in a case like the present, to six years next after the cause of such action arises and not after. The cause of action, it was contended, was that which the arbitrator had found to be the sole cause of the plaintiff's damages, viz., the working of the pillars in 1849 which caused the thrust. The plaintiff, on the other hand, contended that the cause of action did not arise till damage was done, and as the effects of the thrust did not manifest themselves till 1854, the Statute was no bar. The judges of the court, including the late Lord Campbell, decided in favour of the defendant's contention, on the somewhat technical ground that, as one of the ordinary rights of property is that it shall be supported by the strata under and adjoining it, and as the pillars left under Simpson's land were essential for the support of the plaintiff's house their removal in 1849, was depriving the plaintiff of his right of support and therefore gave him a cause of action—six years had elapsed since such cause of

action arose, and the Statute was consequently a bar. From this decision the plaintiff appealed to the Court of Exchequer Chamber, which reversed the judgment of the Court of the Queen's Bench, and this latter decision the House of Lords has just now affirmed."

In conclusion, the writer feels that with so many instances where, under apparently similar circumstances, the results were so different, it seems impossible to come to any definite conclusion as to general principles, and that therefore each case must be decided after consideration of its special characteristics. In cases where the buildings are not of great value he is of opinion that, generally, the wisest course is to work the minerals and let the buildings take their chance, as, even if they are damaged, a slight outlay will in most cases probably make them practically as good as before, while the value of the minerals to be left would in many cases, both to lessor and lessee, far exceed that of the cost of repairs. In such cases the owner of a house, especially if damaged by the working of his own minerals, ought not to be too exacting and expect a new house in place of an old one, thus adding to the already heavy burden of the colliery lessee.

In a recent case, in which the writer was interested, between three and four acres were left for the support of a farmhouse which might not have been damaged at all if the coal had been worked, and probably at the outside £50 would have paid for the injury, if any. The value to the lessors of the coal left was about £450.

In any department of knowledge an accumulation of facts can scarcely be without value, and the writer trusts that the present paper may not prove an exception to the rule.

APPENDICES.

A.—DESCRIPTION OF ILLUSTRATIONS. PLATE VII.

Fig. 1. The rise of the seams worked was at the rate of 1 in 14 to the west, while the surface was nearly level. The goaf in the upper (5 feet) seam, at a depth of 780 feet, and the goaf in the lower (6 feet) seam, at a depth of 960 feet, is shown by the dotted shadings. The house A, standing on unwrought coal, was damaged; all the other houses were undamaged, including the house B, under which both seams had been entirely wrought.

Fig. 2. The goaf in the Upper Main seam, 5 feet thick, at a depth of 780 feet, and the goaf in the Roaster seam, $6\frac{1}{2}$ feet thick, at a depth of 990 feet, is shown by the dotted shadings. A fault, dipping south $6\frac{1}{2}$ feet, is shown by a strong continuous line. The buildings between the points A and B were considerably damaged.

Fig. 3. The Roaster seam, $6\frac{1}{2}$ feet thick, at a depth of 990 feet, was entirely wrought out, and the buildings were considerably damaged.

Fig. 4. The goaf in the Upper Main seam, 5 feet thick, at a depth of 780 feet, and the goaf in the Roaster seam, $6\frac{1}{2}$ feet thick, at a depth of 990 feet, is shown by the dotted shadings. The houses were slightly damaged.

Fig. 5. The Main Coal seam, $3\frac{1}{2}$ feet thick, at a depth of 130 feet, was left

unwrought under the building, and was entirely surrounded by goaf. The buildings were not damaged.

Fig. 6.—The Main Coal seam, 3 feet 10 inches thick, at a depth of 132 feet, was wrought in bords and walls, leaving 62½ per cent. of the coal unwrought in the pillars. The buildings were undamaged.

Fig. 7.—The Main Coal seam, 3½ feet thick, at a depth of 510 feet, was left unwrought under the buildings, which were partly surrounded by goaf. A fault is shown by a strong continuous line. The buildings were not damaged.

Fig. 8.—The Main Coal seam, 3 feet 2 inches thick, at a depth of 390 feet, was wrought in bords and walls, leaving 62½ per cent. of the coal unwrought in the pillars. The building was undamaged.

Fig. 9.—The Main Coal seam, 3 feet 4 inches thick, at a depth of 360 feet, was wrought in bords and walls, leaving 65 per cent. of the coal unwrought in the pillars. Some damage was caused to the buildings.

Fig. 10.—The Main Coal seam, 3 feet 8 inches thick, at a depth of 90 feet, was left unwrought under the buildings, which were surrounded by goaf upon three sides. The building was not damaged.

Fig. 11.—The Brockwell seam, 3 feet 8 inches thick, at a depth of 480 feet, was wrought in bords and walls, leaving 64 per cent. of the coal unwrought in the pillars. The buildings were undamaged, although surrounded by goaf on all sides.

Fig. 12.—The Main Coal seam, 3 feet 4 inches thick, at a depth of 360 feet, was wrought in bords and walls, leaving 55 per cent. of the coal unwrought in the pillars. The buildings were not injured, although goaf was closely adjacent at each side.

Fig. 13.—The Main Coal seam, 3 feet 4 inches thick, at a depth of 420 feet, was wrought in bords and walls, leaving 62½ per cent. of the coal unwrought in the pillars. The buildings stand on a steep hill, inclining heavily to the south. The principal damage to buildings occurred at the point A.

Fig. 14.—The Main Coal seam, 3 feet 2 inches thick, at a depth of 300 feet, was wrought in bords and walls, 66 per cent. of the coal being left unwrought in the pillars. The buildings stand on a steep hill and were not damaged, although surrounded on all sides by goaf.

Fig. 15.—The Main Coal seam, 2 feet 10 inches thick, at a depth of feet, was wrought in bords and walls, leaving 64 per cent. of the coal unwrought in the pillars. The buildings were undamaged, although surrounded with goaf; the pillars were afterwards removed, and the buildings were only slightly damaged.

Fig. 16.—The Main Coal seam, 3 feet 4 inches thick, at a depth of 192 feet, dips eastward at 1 in 12. The workings were on the bord-and-wall system, leaving 60 per cent. of unwrought coal in the pillars. Faults are shown by strong continuous lines. A small area of goaf was made, and the buildings marked A, B, C, D, E, and F were seriously damaged.

Fig. 17.—The seam, 4½ feet thick, at a depth of 720 feet, was wrought in bords and walls, and goaves formed on all sides of the buildings, which were not damaged.

B.—SECTION OF A SHAFT SUNK THROUGH THE NEW RED MARLS AND KEUPER SANDSTONES INTO COAL-MEASURES, REFERRED TO IN FIG. 1, PLATE VII.

No.	Description of Strata.	Thick- ness of Strata.		Depth from Surface.	No.	Description of Strata.	Thick- ness of Strata.		Depth from Surface.		
		Ft.	In.				Ft.	In.			
1	Red marls, with thin bands of grey shale and fine-grained sandstones (skerries)..	143	0	143	0	2	Sandstone	...	3	0	
						3	Red marl...	...	21	6	
						4	Sandstone	...	2	3	
						5	Red marl...	...	36	0	
						6	Sandstone	...	18	0	
										146	0
										167	6
										169	9
										205	9
										223	9

APPENDIX B.—Continued.

No.	Description of Strata.	Thick- ness of Strata.		Depth from Surface.	
		Ft.	In.	Ft.	In.
7	Red marl...	15	0	238	9
8	Sandstone ...	3	0	241	9
9	Red marl...	72	0	313	9
10	Sandstone ...	3	0	316	9
11	Bind ...	7	6	324	3
12	COAL ...	1	4	325	7
13	Fireclay or under- clay ...	5	0	330	7
14	Bind ...	11	0	341	7
15	Grey sandstone ...	10	0	351	7
16	Blue bind ...	20	0	371	7
17	COAL ...	4	0	375	7
18	Bat ...	0	9	376	4
19	COAL ...	1	7	377	11
20	Blue bind ...	42	8	420	7
21	Shale ...	0	4	420	11
22	COAL ...	7	0	427	11
23	Hard clunch or clay ...	5	0	432	11
24	Soft bind...	26	0	458	11
25	COAL ...	5	0	463	11
26	Bat ...	0	6	464	5
27	COAL ...	4	6	468	11
28	Clunch or under- clay ...	2	0	470	11
29	Bind and clunch	28	0	498	11
30	Bed, with fossil shells ...	1	0	499	11
31	Hard sandstone...	2	6	502	5
32	Stony bind ...	4	6	506	11
33	Bind and shale ...	9	6	516	5
34	COAL (soft) ...	1	0	517	5
35	Fireclay ...	5	0	522	5
36	Bind ...	7	6	529	11
37	Bat ...	0	5	530	4
38	COAL ...	1	6	531	10
39	Sandstone ...	5	0	536	10
40	Bind ...	9	0	545	10
41	Fireclay ...	1	3	547	1
42	COAL ...	2	3	549	4
43	Bat ...	0	2	549	6
44	COAL ...	1	8	551	2
45	Fireclay ...	2	6	553	8
46	Clunch and bind, with ironstone..	1	6	555	2
47	Blue bind, with courses of iron- stone ...	20	0	575	2
48	White sandstone..	5	0	580	2
49	COAL ...	2	10	583	0
50	Clunch, with courses of ironstone ...	4	6	587	6
51	Bind, with courses of ironstone ...	1	6	589	0
52	Stony bind ...	8	6	597	6
53	Sandstone ...	19	0	616	6
54	Bind ...	0	9	617	3
55	White sandstone..	0	6	617	9
56	Fireclay ...	0	6	618	3
57	COAL ...	3	4	621	7
58	Clunch or under- clay ...	4	9	626	4
59	Stony bind ...	9	6	635	10
60	Dark bind ...	24	6	660	4
61	Fireclay ...	0	6	660	10
62	COAL ...	4	6	665	4
63	Clunch ...	9	0	674	4
64	Black bind ...	9	6	683	10
65	Stony bind ...	15	3	699	1
66	Sandstone ...	4	9	703	10
67	Bind, with a part- ing (1 foot) of sandstone ...	6	0	709	10
68	COAL ...	0	10	710	8
69	Fireclay ...	0	3½	710	11½
70	COAL — <i>Upper Main Seam</i> ...	5	0	715	11½
71	Fireclay ...	5	3	721	2½
72	Bind, containing nodules of iron- stone ...	11	3	732	5½
73	Fireclay with iron- stone ...	1	6	733	11½
74	Stony bind ...	4	6	738	5½
75	Bind ...	20	6	758	11½
76	Fireclay ...	0	6	759	5½
77	COAL ...	2	0	761	5½
78	Fireclay ...	10	0	771	5½
79	Bind ...	5	0	776	5½
80	Sandstone ...	4	6	780	11½
81	Stony bind ...	25	0	805	11½
82	Bind ...	10	6	816	5½
83	Bat ...	1	0	817	5½
84	COAL ...	4	6	821	11½
85	Fireclay ...	4	0	825	11½
86	Sandstone ...	15	0	840	11½
87	Shale ...	4	0	844	11½
88	Fireclay ...	0	3	845	2½
89	COAL ...	3	3	848	5½
90	Fireclay ...	9	0	857	5½
91	COAL ...	3	1	860	6½
92	Stony bind ...	16	6	877	0½
93	Sandstone ...	9	0	886	0½
94	Stony bind ...	3	0	889	0½
95	Sandstone ...	1	8	890	8½
96	Bind ...	19	0	909	8½
97	Shale ...	1	0	910	8½
98	COAL ...	3	7	914	2½
99	Fireclay ...	9	6	923	9½
100	COAL — <i>Lower Main or Roaster Seam</i> ...	8	3	932	0½

C.—SECTION OF A SHAFT SUNK THROUGH MARLS AND KEUPER SANDSTONES
INTO THE COAL-MEASURES, REFERRED TO IN FIG. 2, PLATE VII.

No.	Description of Strata.	Thick- ness of Strata. Ft. In.	Depth from Surface. Ft. In.	No.	Description of Strata.	Thick- ness of Strata. Ft. In.	Depth from Surface. Ft. In.
1	Soil, marl, and skerry ...	190 0	190 0	56	Clunch with iron- stone balls ...	3 4	427 2
2	Skerries ...	1 0	191 0	57	COAL ...	5 0	432 2
3	Marl ...	4 3	195 3	58	Bat ...	1 0	433 2
4	Skerry ...	1 0	196 3	59	COAL ...	2 9	435 11
5	Marl ...	8 9	205 0	60	Bat ...	0 4	436 3
6	Skerry ...	1 0	206 0	61	Fireclay ...	1 0	437 3
7	Skerry ...	5 0	211 0	62	Bind ...	1 6	438 9
8	Marl ...	22 9	233 9	63	Rock ...	3 6	442 3
9	Sandstone rock ...	1 0	234 9	64	Bind ...	3 0	445 3
10	Marl ...	5 0	239 9	65	Rock ...	6 3	451 6
11	Skerry ...	1 0	240 9	66	Bind ...	4 7	456 1
12	Marl ...	5 0	245 9	67	Rock ...	1 1	457 2
13	Marl and skerry...	10 0	255 9	68	Bind ...	1 2	458 4
14	Marl ...	0 7	256 4	69	Rock ...	0 10	459 2
15	Skerry ...	1 0	257 4	70	Bind ...	2 9	461 11
16	Sandstone rock ...	6 2	263 6	71	Rock ...	2 11	464 10
17	Marl ...	1 2	264 8	72	COAL ...	6 8	471 6
18	Marl and skerry...	5 6	270 2	73	Bind ...	21 8	493 2
19	Skerry ...	1 0	271 2	74	Stone bind ...	1 0	494 2
20	Marl ...	8 9	279 11	75	Bind ...	3 0	497 2
21	Skerry ...	1 0	280 11	76	Ironstone balls ...	0 6	497 8
22	Marl ...	4 0	284 11	77	Bind ...	3 10	501 6
23	Sandstone rock ...	5 3	290 2	78	Ironstone ...	0 2	501 8
24	Marl ...	2 6	292 8	79	Bind ...	0 3	501 11
25	Marl ...	7 0	299 8	80	Ironstone ...	0 2	502 1
26	Conglomerate ...	8 4	308 0	81	Bind ...	4 4	506 5
27	Marl ...	3 6	311 6	82	Ironstone ...	0 2	506 7
28	Rock ...	7 7	319 1	83	Bind ...	0 6	507 1
29	Bind ...	4 0	323 1	84	Ironstone... ..	0 1½	507 2½
30	Bat ...	1 7	324 8	85	Bind ...	0 9	507 11½
31	COAL ...	0 4	325 0	86	Ironstone ...	0 1½	508 1
32	Clunch ...	6 6	331 6	87	Bind ...	0 10	508 11
33	Bind ...	1 6	333 0	88	Dark bind ...	0 10	509 9
34	Clunch ...	4 1	337 1	89	Bind ...	2 0	511 9
35	Whinstone rock...	25 8	362 9	90	Ironstone ...	0 2	511 11
36	Bat ...	1 6	364 3	91	Bind ...	5 4	517 3
37	Clunch ...	7 9	372 0	92	COAL ...	5 0	522 3
38	COAL ...	0 6	372 6	93	Bat ...	1 4	523 7
39	Fireclay ...	1 6	374 0	94	COAL ...	5 2	528 9
40	Bat ...	0 4	374 4	95	Clunch ...	3 1	531 10
41	Clunch ...	9 6	383 10	96	Bind ...	4 5	536 3
42	COAL ...	1 6	385 4	97	Ironstone ...	0 2	536 5
43	Fireclay ...	1 3	386 7	98	Bind ...	1 0	537 5
44	Sandstone rock ...	3 5	390 0	99	Ironstone ...	0 2	537 7
45	Ironstone ...	0 4	390 4	100	Bind ...	0 2	537 9
46	Rock ...	7 1	397 5	101	Ironstone ...	0 2	537 11
47	Peldon ...	1 0	398 5	102	Bind ...	3 0	540 11
48	Bind ...	1 9	400 2	103	Ironstone ...	0 3	541 2
49	Fireclay ...	0 6	400 8	104	Bind ...	1 8	542 10
50	Rock ...	3 6	404 2	105	Ironstone ...	0 3	543 1
51	Ironstone ...	0 2	404 4	106	Bind ...	2 0	545 1
52	Bind ...	11 0	415 4	107	Bat ...	0 4	545 5
53	Ironstone ...	0 2	415 6	108	Clunch ...	2 0	547 5
54	Bind ...	2 0	417 6	109	Bind ...	2 0	549 5
55	Bind ...	6 4	423 10	110	Stone bind ...	6 4	555 9

APPENDIX C.—Continued.

No.	Description of Strata.	Thick- ness of Strata. Ft. In.	Depth from Surface. Ft. In.	No.	Description of Strata.	Thick- ness of Strata. Ft. In.	Depth from Surface. Ft. In.
111	Cank ...	0 8	556 5	161	Bind ...	3 7	769 7
112	Bind ...	13 0	569 5	162	COAL — Upper		
113	Dark bind ...	2 3	571 8		<i>Main Seam</i> ...	5 6	775 1
114	COAL ...	1 6	573 2	163	Fireclay ...	1 6	776 7
115	Bat ...	0 8	573 10	164	Bind ...	8 7	785 2
116	Clunch ...	10 11	584 9	165	COAL ...	1 4	786 6
117	Rock ...	0 9	585 6	166	Fireclay ...	1 3	787 9
118	Bind ...	1 3	586 9	167	Clunch ...	2 5	790 2
119	Bat ...	0 6	587 3	168	Ironstone balls ...	1 0	791 2
120	Bind ...	4 3	591 6	169	Bind ...	5 3	796 5
121	Bat ...	2 9	594 3	170	Bind ...	8 0	804 5
122	Bind ...	3 3	597 6	171	Ironstone balls ...	1 0	805 5
123	Bat ...	0 9	598 3	172	Bind ...	7 10	813 3
124	COAL ...	1 0	599 3	173	Rock ...	0 6	813 9
125	Bind ...	8 0	607 3	174	Bind ...	3 2	816 11
126	Cank ...	2 0	609 3	175	Cank ...	2 0	818 11
127	Bind ...	10 6	619 9	176	Bind ...	6 0	824 11
128	COAL ...	5 0	624 9	177	Rock ...	3 6	828 5
129	Clunch ...	1 8	626 5	178	Bind ...	3 0	831 5
130	Fireclay ...	3 2	629 7	179	Stone bind ...	12 0	843 5
131	COAL ...	0 2	629 9	180	COAL ...	3 6	846 11
132	Bind ...	6 6	636 3	181	Bat ...	3 0	849 11
133	Stone bind ...	1 9	638 0	182	CANNEL COAL	2 3	852 2
134	Bind ...	5 3	643 3	183	Clunch ...	1 6	853 8
135	Bind ...	2 9	646 0	184	Bind ...	5 6	859 2
136	Rock ...	4 9	650 9	185	Bind ...	8 0	867 2
137	Bind ...	2 3	653 0	186	Shale ...	5 0	872 2
138	Bind ...	10 6	663 6	187	COAL ...	3 0	875 2
139	COAL ...	2 4	665 10	188	Fireclay ...	6 0	881 2
140	Bat ...	0 6	666 4	189	Bat ...	6 0	887 2
141	COAL ...	0 10	667 2	190	Clunch ...	1 0	888 2
142	Fireclay ...	9 0	676 2	191	COAL ...	3 6	891 8
143	Sandstone rock ...	11 0	687 2	192	COAL and bat...	1 2	892 6
144	Bind ...	9 2	696 4	193	Fireclay ...	2 8	895 6
145	COAL ...	1 6	697 10	194	Sloom ...	0 8	896 2
146	Bat ...	0 5	698 3	195	Bind with iron- stone balls ...	7 4	903 6
147	CANNEL COAL	2 2	700 5	196	Bind ...	16 4	919 10
148	Sloom ...	0 5	700 10	197	Bind ...	17 2	937 0
149	Bind ...	3 5	704 3	198	Bind ...	11 8	948 8
150	Rock ...	9 4	713 7	199	Bat ...	0 8	949 4
151	Bind ...	3 10	717 5	200	COAL ...	3 9	953 1
152	Stone bind ...	13 6	730 11	201	Fireclay ...	5 10	958 11
153	COAL ...	5 6	736 5	202	COAL — Lower		
154	Clunch ...	3 5	739 10		<i>Main or Roaster</i>		
155	Smut ...	1 7	741 5		<i>Seam</i> ...	9 2	968 1
156	Bind ...	4 5	745 10	203	Fireclay ...	11 8	979 9
157	Sandstone rock ...	6 8	752 6	204	Bat ...	1 4	981 1
158	Sandstone rock ...	3 4	755 10	205	Bind ...	10 0	991 1
159	Bind ...	8 4	764 2	206	Rock ...	6 1	991 2
160	Rock ...	1 10	766 0				

Mr. T. A. SOUTHERN (Derby) said the paper was an interesting one on an important subject. A case was mentioned of a pillar of a different width on each side being left to support a church; it would be well to have some explanation of the circumstances. In the remarks of Mr. Steavenson embodied in the paper certain conditions were enumerated upon which an injury depended. He thought to that should be added the structure and form of the surface. If the beds were at an inclination the gradient should be given.

The PRESIDENT said general laws had been laid down in reference to the area of pillars required for the support of buildings, but in his opinion, whenever practicable, it was desirable to take out the whole of the coal. Some lessors objected to this course, and he thought it was practically impossible to do so without causing slight damage. It was known that a seam of coal could not be worked without causing subsidence of the surface, which might affect buildings contrary to their expectations, sometimes causing damage where very little had been anticipated. He wished Mr. Spencer had recorded his views as to the area of pillars he would suggest should have been left under the circumstances mentioned in his paper, mining engineers have previously done this, but possibly he may have other views on the subject. He proposed a vote of thanks to Mr. Spencer for the trouble he had taken in preparing his paper.

Mr. A. SOPWITH (Cannock Chase) seconded the vote of thanks. He agreed that it was difficult to lay down rules for leaving pillars under buildings, but a valuable addition would be made to the *Transactions* if they could obtain from the different mining districts actual facts as to subsidences and what the damage was. It was possible to lower the surface 8 or 9 feet without damage, but a great deal depended on faults and other conditions, more especially with regard to the surface-strata and the surface-soil. He had seen buildings as much damaged by drainage of water as by coal-workings; this was notably the case in his own district where a surface-drain was put in. The colliery-workings were about 200 yards from the building which sustained considerable damage, which was undoubtedly caused by the water being drained away.

The vote of thanks was carried unanimously.

Mr. W. SPENCER acknowledged the compliment, and said he agreed with all the remarks that had been made. In reply to Mr. Southern, he regretted he could not give reasons for the different widths of coal left on different sides of the church—he gave the information as it had been supplied to him, and supposed it was in consequence of the dip of the

measures or the configuration of the surface. The dip of the measures in the other cases could be supplied afterwards; it was, however, in all the cases, very moderate. He hoped other members would give their experience where the strata or the surface or both were steep, such records would be valuable.

Mr. HENDERSON exhibited and explained the instrument described in the following paper on a "Rapid Traverser":—



RAPID TRAVERSER.

BY JAMES HENDERSON, M. INST. C.E.

The rapid traverser instrument is based on what is known as the plane-table system of surveying, and by its means enclosed and open traverses, both at the surface and underground, can be accomplished and subsequently laid down on paper with very great rapidity and accuracy.

Unlike the plane-table, however, it is not intended that the rapid traverser should be used for plotting the survey in the field, a process involving many great objections, but this is done afterwards in the drawing office, with the aid of a parallel rolling-ruler and scale, and the result is highly satisfactory in every respect.

The traverser (Fig. 1, Plate VIII.) may briefly be described as a circular metal table of about 10 inches in diameter, mounted on an ordinary tripod stand with the usual adjusting screws, having a brass alidade with an ordinary sight at each end revolving round a fixed centre-pin. The leading-sight *a*, and the back-sight *b* are attached to the lower frame of the alidade.

Upon the face of the table a disc *e* of celluloid, Willesden waterproof paper, or other suitable material, is securely attached by means of several small brass screw-nuts and bolts *f*, and a brass holding-down plate *g*, over which the alidade by means of a groove can travel freely. Celluloid is to be preferred to any other material, as it requires no protection from the weather, and does not buckle under the effects of rain or water.

This disc is divided into five concentric rings slightly scratched or grooved on the celluloid, and the fiducial edge of the alidade is also thus divided with a small notch *c* at each annulus for the purpose of figuring or lettering the line observed and pencilled on the disc.

The object of these concentric rings is not only to allow of separate surveys being accomplished on one disc, but also to avoid overcrowding of direction-lines in any particular spot in the disc.

The quadrant can be attached, when required by the screws *d*, *d*.

By means of the usual clamping-screws the table carrying the celluloid disc can be clamped to the stand and the alidade with the sights attached to the table when required.

The rapid traverser is worked as follows :—The instrument is set on its stand in the usual way, and levelled by means of a small portable spirit-level or by a level fixed to the alidade, and the alidade is sighted (by a back sight) on the starting point of the survey, and both the alidade and the table are securely fixed by their respective clamps.

The direction of this first line of the survey is then marked with a finely pointed H H pencil on the selected annulus of the disc at two points equidistant from the centre, and duly lettered or figured within the notch cut in the fiducial edge of the alidade for this purpose.

The alidade is then unclamped and sighted to the forward stand or tripod, and clamped (three tripods being recommended for properly conducting a traverse), and the direction of the second line of the survey marked on the annulus as before.

The traverser is then removed from its stand, and fixed with the alidade still clamped, on the forward stand, and sighted back to the tripod it formerly occupied, and clamped.

This done the alidade is unclamped, sighted to another forward stand; it is again clamped and the direction of the third line of the survey duly marked and figured on the disc, and so on, for the remainder of the traverse, the surveyor only recording in his book the lengths of the several lines, with offsets as in the ordinary way.

The magnetic meridian is taken at any convenient spot in the course of the traverse by means of a trough compass placed temporarily against the back edge of the alidade, and the line thus given pencilled on the disc, establishing the polarity of the whole of the survey.

The same disc on its table can be used on any disconnected part of a survey by again placing the trough compass against the alidade clamped on the previously pencilled north line, the table being moved until the needle points to the north.

The leading direction of each line is given by simply marking a half-arrow against the line before moving the alidade (Fig. 2), thereby showing the course or direction of each line.

The fiducial edge of the alidade should always be to the surveyor's right hand, he facing in the direction of the next traverse-line, not only thereby affording greater facility for drawing and figuring the lines on the disc, but also preventing any chance of misplacing the guiding half-arrow referred to.

In order to use the traverser on hilly ground the sights at each end of the alidade are marked in degrees up to 25, so that by looking over the

top of the back sight and getting the forward object in line with one of the divisions the angle of declination can be at once read and recorded.

Where greater accuracy in vertical angles is required, such as in diagonal shafts of a mine, a quadrant, or properly speaking, a semicircle, is attached to the alidade, and the angles read to minutes, as in the ordinary theodolite or miner's dial.

The method of using the traverser having now been explained, it only remains to describe its application in the drawing office. One or more meridian lines having been drawn on the intended plan, the disc (Fig. 2, Plate VIII.) is removed from its circular table and placed, with the north line already marked on it in the field, in its proper position and kept there by a weight or two. A heavy metal rolling parallel-ruler is then applied to each line of the survey in succession, as shown on the disc, and correctly marked off on the plan. In a large survey the disc can be moved to any one of the meridian lines as required. In short, the disc becomes a protractor of great accuracy, and errors in misplotting can seldom occur, the actual lines drawn in the field being, if carefully figured or numbered, represented in counterpart on the plan.

Fig. 2, Plate VIII., is a reduced facsimile of the disc, used in the survey of Carnon Estate, parish of Feock, county of Cornwall; and Fig. 3, shows the draft lines of the survey produced from the disc.

For future reference the disc itself may be kept, the name and date of the survey being recorded thereon, or the magnetic bearings of the lines may be read off with facility, and the same entered in the field or survey book, when the celluloid disc can be cleaned with soap and water or by means of india-rubber and rendered quite fit for the next occasion.

A convenient method of reading off the bearings is to place the disc in the centre of an ordinary cardboard protractor, which has been cut out for the purpose, both being pinned to the board. A central metal spill projects from the board, and by means of an alidade constructed so as to work on this spill the bearings are read off with ease and rapidity.

The inventor of the rapid traverser has used this instrument with great success both underground, in mines, and in surface surveys. Its simplicity will be at once seen and recognized by the professional surveyor, who, when he knows that all his survey lines are being truthfully registered with the very least degree of trouble to himself, will no doubt appreciate its merits.

The inventor was at first apprehensive that the wet and dirt to which the instrument would be exposed when used in mines would be a serious drawback to its application, but from experience he is able to say that

celluloid discs are not liable to injury underground. A dash of clean water applied at any time will effectually remove any dirt, without the slightest obliteration of the pencil marks, which can be made as readily and as permanently when the disc is under a film of water as when it is perfectly dry.

The rapid traverser can be readily used for setting out in the field, lines at right angles, or at any required angle, the necessary lines on the disc being drawn in the office beforehand. For rapid triangulation-work the traverser now described can be used with great advantage. A suitable base-line having been measured, it only needs to set up the traverser at each end in succession, when the bearings of all required distant points can be noted on the disc, and the work subsequently plotted in the office to any scale.

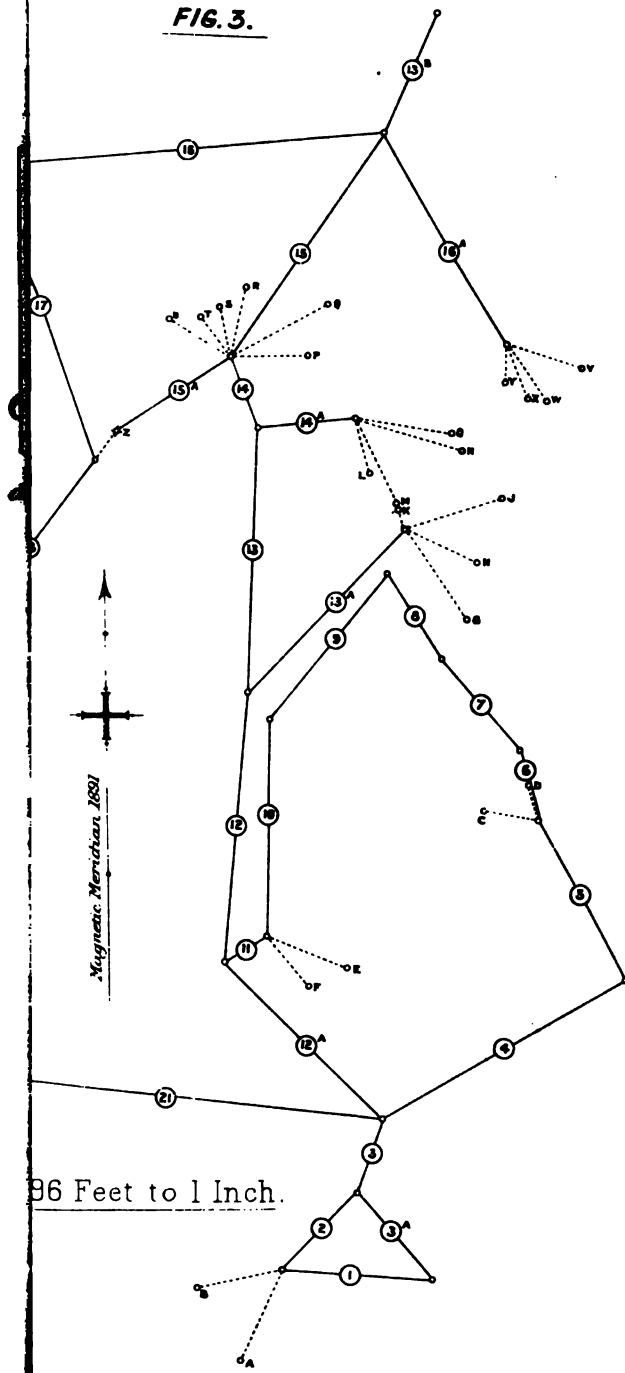
The instrument being very portable, requiring no skilled manipulation, no reading of angles, and no subsequent calculation, should be found most useful for military purposes. It could be worked with rapidity in all weathers, and the salient points of the country, the position of the enemy, etc., subsequently mapped with speed and accuracy.

The traverser could also be used as a range-finder and with a previously measured base-line, traversers worked simultaneously from both ends, the range of even a moving object could be discovered with an accuracy approximate enough to be of considerable advantage.

On the motion of the PRESIDENT a vote of thanks was accorded to Mr. Henderson for his paper.

The following paper, by Mr. John Milne, "On Earth Pulsations and Mine Gas," was read, and a tromometer was kindly exhibited and explained Mr. Horace Darwin:—

FIG. 3.



**SKELETON MAP OF TRAVERSE LINES
AS RULED OFF FROM ADJACENT DISC**



ON EARTH PULSATIONS AND MINE GAS.

BY JOHN MILNE, F.R.S., F.G.S.

1.—INTRODUCTION.

In the following pages the writer chiefly refers to the result of his own observations in Japan to which is added a short critical examination of work carried out in Italy.

A description of the observations made during the last twelve months is here given for the first time, while work undertaken by the author during previous years will be found in the following publications:—

1. "Observations of Tremors, etc., in Takashima Colliery," *Japan Gazette*, January 12th, 1884.
2. "Earth Tremors," *Transactions of the Seismological Society of Japan*, 1883, vol. vii., page 1.
3. "Earth Tremors in Central Japan," *Transactions of the Seismological Society of Japan*, 1887, vol. xi., page 1.
4. "Earth Tremors in Central Japan," *Transactions of the Seismological Society of Japan*, 1888, vol. xiii., page 7.
5. "Earth Tremors and the Wind," *Journal of the Royal Meteorological Society*, 1888, vol. xiv., page .
6. "Reports of Committee on the Earthquake and Volcanic Phenomena of Japan," *Reports of the British Association*, 1881, page 200 ; 1882, page 205 ; 1883, page 211 ; 1884, page 241 ; 1885, page 362 ; 1886, page 413 ; 1887, page 212 ; 1888, page 422 ; 1889, page 295 ; 1890, page 160 ; 1891, page 123 ; and 1892, page 93.

In the investigations detailed in the above papers, notwithstanding the fact that tables were given to show that tromometric movements followed barometric gradients, the author attributed the occurrence of tremors to local or distant winds which might be the result of these gradients. Investigations carried on during the last year, having thrown a clearer light on the nature of these motions, the writer no longer regards them as rapidly recurring elastic vibrations, usually called earth

tremors, but rather as comparatively slow wave-like undulations of the soil, which, rather than being a secondary effect of barometric fluctuations may be an immediate consequence of such changes.

Movements of this character may have a direct connexion with the escape of gas from the coals of fiery mines, they may influence the results arrived at in pendulum experiments, they may affect the accuracy of an ordinary chemical balance, and may have a relationship to many astronomical and physical investigations; in the following pages the author proposes to give an outline of various researches bearing on these imperfectly understood phenomena.

2.—ON THE ESCAPE OF MINE GAS IN RELATION TO EARTH PULSATIONS.

To determine whether the escape of gas at a coal-mine had any relationship to earth movements, in 1883 the writer prepared a number of instruments to be used at the Takashima colliery near Nagasaki in Japan: the workings of which are partly beneath the bed of the Pacific Ocean. The movements to be looked for were the so-called earth tremors—which are motions altogether different in character from earthquakes—and from disturbances due to the bending of superincumbent strata by the rising and falling of the tide. Every facility was given by the mine-owners for the establishment of an under-ground observatory—benches were cut in an old working, while a tromometer, a microphone, a specially-designed apparatus to measure and record yielding of the roof, a seismograph, and other instruments were set up. A few weeks later a fall occurred, and the instruments have remained buried ever since. It may be here remarked that the seismographs then employed, belowground and also on the surface, were installed not because it was supposed that they would give records showing any connexion with the issue of mine gas but more for the purpose of measuring the difference between motion recorded underground and that which was felt on the surface. They were of a very old type, designed by the writer, and practically identical with a seismoscope used at Marsden.*

In consequence of the fact that Takashima is some 700 miles distant from Tokio, where the writer resides, but more especially in consequence of the death of Mr. John Stoddart, the resident engineer at the mine,

* *Trans. N. E. Inst. Min. Eng.* (Seismometer used at Marsden). vol. xxxvii. , Plate VIII.

who had undertaken charge of the instruments, no attempt has been made to re-establish them. Reference is made to these investigations which had but a bare commencement, in a paper by Mr. M. Walton Brown "On the Observation of Earth-shakes or Tremors, in order to Foretell the Issue of Sudden Outbursts of Fire-damp,"* in a report to the British Association on the "Volcanic Phenomena of Japan," Report for 1886, page 413, and again by M. G. Chesneau in the *Annales des Mines*, 1888, series 8, vol xiii, page 389.

In Mr. M. Walton Brown's paper he gives a comparison between the frequency of earthquakes in Great Britain and the fatal explosions of gas in collieries, showing that, roughly speaking, earthquakes have been more frequent during the winter months when gas explosions have been frequent. Although Mr. Brown distinctly points out that there may be undulatory and vibratory motions in the earth's crust which may be related to the outflow of gas, in the report of the committee appointed to enquire into the observations of earth tremors in mining districts,† we only find the records of instruments which could record the occurrence of earthquakes.

In France, however, at Douai, the liberation of fire-damp in connexion with the movements of tromometers has received careful attention, and the results first obtained are indicated in the *Annales des Mines*.‡ A fuller account of these investigations is given in the paper already referred to by M. Chesneau. By means of a Pieler lamp the gas in the returns was measured daily at 6 a.m., at which time on account of work ceasing at 5.30 a.m., the quantity of gas was as far as possible independent of the quantity of coal being extracted.

Barometric observations were made on the surface and underground. The tromometric records were obtained from a "tromomètre normal" consisting of a pendulum 1.50 metres long, the style of which was observed with a microscope containing a micrometric scale.

The results obtained were briefly as follows:—

I. *Microseismic Disturbances and Fire-damp*.—The curves agreed in direction on 81 days; the curves disagreed in direction on 46 days; the curves practically followed a horizontal line on 51 days; total, 178 days.

II. *Barometrical Fluctuations and Fire-damp*.—The curves disagreed in direction on 75 days; the curves agreed in direction on 51 days; the curves practically follow a horizontal line on 54 days; total, 180 days.

* *Trans. N. E. Inst. Min. Eng.*, vol. xxxiii., page 179.

† *Ibid.*, vol. xxxvii., page 55.

‡ Vol. ix., 1886, page 258.

III. *Microseismic Movements and the Appearance of Fire-damp within at least 24 hours.*—When microseisms have exceeded 1 division, the curves agreed 7 times and disagreed 4 times; when microseisms have been between $\frac{1}{2}$ and 1 division, the curves agreed 18 times and disagreed 7 times; when microseisms have been 0, fire-damp has decreased 9 times and increased or been constant 4 times. For maxima or minima of fire-damp not included in the above, there were 9 cases of concordance and 2 of discordance.

IV. *Comparison of Percentage of Fire-damp and Tremors.*—When fire-damp has exceeded 0·5 per cent., movements were always observed, that is on four occasions. When fire-damp has been below 0·5 and above 0·25 per cent., movements have been observed thirteen times, and seven times they were not observed.

V. *Barometric Variations and Fire-damp.*—When there has been a rise and fall of 20 millimetres or more within twenty-four hours, fire-damp has been observed twice and not observed once. With a variation of 15 millimetres to 20 millimetres, it has been observed four times and not observed once. With a variation of 15 millimetres to 10 millimetres, it has been observed five times and not observed on seven occasions.

VI. *Percentage of Fire-damp and Barometric Fluctuation.*—When fire-damp during twenty-four hours has exceeded 0·5 per cent., in three cases there has been agreement with barometric movements and in two cases disagreement. When fire-damp has been between 0·5 and 0·25 per cent., there have been eleven cases of agreement with barometric fluctuations and thirteen cases of disagreement.

In the discussion of results M. Chesneau points out that microseismic movements are more clearly related to the escape of gas than barometric movements. On some occasions this relationship between the three phenomena has been extremely well marked, as for example on December 8th, 1886.

A point in connexion with this, which although not referred to by M. Chesneau, can hardly have escaped his attention, is that although the increase in microseismic movements, the increase in gas, and the barometric fall commenced simultaneously, the microseismic movements reached a maximum about six hours before the gas reached a maximum, whilst the lowest point of the barometric curve occurred even twelve hours later, or eighteen hours after the maxima of the barometric movements.

To know whether these earth movements or even their maxima are always somewhat in advance of the escape of fire-damp is a matter for future experiments and, in the writer's opinion, can only be deter-

mined by the use of instruments yielding a continuous automatic record, a form of which is described in this paper. The only other work with which the writer is acquainted bearing on the matter now under consideration is a comparison between the monthly curves of microseismic activity in Italy and a number of explosions of fire-damp recorded in Germany. The latter, which are arranged as a monthly curve, show a close relationship with the microseismic curve.

3.—OBSERVATIONS OF EARTH PULSATIONS IN JAPAN.

As the results at which the writer has arrived in Japan are in several respects very different from those arrived at in Italy; these will be briefly enumerated: the object being to compare the conditions accompanying the appearance of tremors with what we know respecting the escape of fire-damp.

The instruments employed by the writer have been various, one of the first being similar to the normal tromometer of Bertelli and Rossi. As it often happened that the pendulums showed deflections of the vertical, for several years records were taken of a pair of good astronomical levels. At the time of a typhoon, when there are sudden changes in barometric pressure, it was observed that the bubbles of these instruments would intermittently pulsate through a range of say 1 millimetre, conveying the idea that the column on which they stood was being rapidly raised and lowered. This was the first indication obtained by the writer that the ground might at times be subjected to rapidly-recurring tilts. As indicators of gradual changes in level, notwithstanding all ordinary precautions being taken to eliminate effects due to change of temperature, the writer arrived at the conclusion, reached a long time previously by M. d'Abbadie, that records obtained from these instruments were untrustworthy. For example, it was found that with two levels placed parallel to each other the bubble of the one might move to the right, whilst the bubble of the other crept towards the left.

Other instruments of the pendulum type were short pendulums consisting of a shot suspended by a fibre inside a vacuum tube. These pendulums were from 2 to 6 inches in length. Other pendulums, which will record elastic vibrations like those produced by a passing carriage, were essentially very small plates or cylinders suspended near their upper edges. Their movements were observed by means of a microscope or by watching a spot of light, reflected by a mirror which they carried, move backwards and forwards across a scale. For a long period earth movements were observed by instruments similar in type to the mirror-

pendulum arrangement employed by Messrs. G. and H. Darwin in their well-known experiments on lunar attraction in the Cavendish laboratory.

The instrument which was used very successfully for several years and which gave excellent results consisted of a heavy pendulum about 1 foot in length the vibrations of which were amplified by the motion of a long radiating pointer. In general appearance this was not unlike the instrument which was afterwards employed at Marsden, but instead of the pointer magnifying the minute motion of the pendulum and the pointer scale being arranged the motion about one hundred times. For an extremely sensitive and an induction coil, sparks were discharged every 1/2 minute from the end of the pointer which perforated a series of paper having a regular spiral beneath. When there were no tremors the holes passed in a series of holes following each other in a straight line moving down again, but when there were tremors, the paper was perforated in a series of holes in all directions round the normal position of the tip of the pointer. From the position of the holes, and the number of paper holes which they were distributed, the duration of tremors, the nature and their number, intensity was clearly determinable.

Although many of the reader's observations were based on a comparison of these records with the ordinary weather maps, he recognized

that, on account of the natural period of the pendulum synchronizing or non-synchronizing with the period of the impulses from tremors and from its inertia which began swinging when earth-movements might have ceased, to study the nature of these movements more closely a totally different type of instrument was required. The form adopted is essentially an exceedingly light and at the same time sensitive form of optical pendulum which are constructed as follows:—*a b* is an aluminium wire supported in an horizontal position by the silk fibre *a c*—

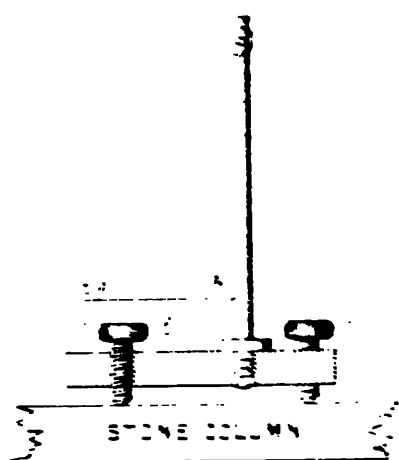


FIG. 1.

A small galvanometer-mirror is attached to *a*, while the needle tipped point of the wire rests on the light pivot at *b*. By means of the levelling-screws *d* & *f* the pendulum may be arranged to have any degree of stability. The

adjustment given by the writer is such that a b swings with a period of about five seconds. The less stability given to the system the more sensitive does it become to a change of level. A beam of light from a small kerosene lamp, having passed through a vertical slit and then a lens, impinges on the mirror and is reflected back upon a scale about 3 feet distant, where it is seen practically as a vertical line of light, and this is always more or less in motion. By turning a screw of the support, so that the bedplate is tilted to say 1 in 900, the image of light is displaced about 9 inches, and as the readings are to millimetres, a tilt of 1 in 200,000 is easily noted. When the image is practically steady at any particular point on the scale, and the mirror is caused to swing, in a few minutes it returns to its normal position. A spirit lamp burning outside but close to the glass cover, produces no appreciable change. In a complete apparatus, two of these instruments are placed so that their planes of swing are at right angles and both may reflect portions of the same beam of light. By lifting the scale—which is movable—on which the readings are noted the vertical beam crosses a horizontal slit opening into a box, in which there is a photographic plate moving slowly by clock-work. For ordinary work the plates used moved at the rate of 12 inches in twenty-hours, but for a few special experiments they were caused to move rapidly, so that each vibration was recorded separately, and from the resulting diagram the period and amplitude of these could be measured.

To economize space, the plate is now replaced by a drum carrying a photographic film, so arranged that the apparatus can be used in an ordinary room, the box containing the roll can be removed to a dark room in daylight, and at any moment during the day or night the movements being recorded can be watched and measured. From observations and from photographs we know that when the mirrors are caused to swing their period is constant, while when they are moving during a tremor storm their period is variable. The slowly-moving plates show that during a microseismic storm that maximal disturbances occur at intervals of from four to eight minutes. If two of these instruments are placed side by side to record the same component of motion, we see that they invariably start at the same time and in the same direction, and it is difficult to escape from the conclusion that they have been simultaneously tilted. They do not commence gently, but suddenly, as if the column on which they stand, which is a massive stone structure built many years ago to carry an equatorial telescope, had been tilted by a wave. During a given storm the direction of these impulses are fairly constant.

it would be found that within 200 or 300 miles a heavy gale was blowing. The suggestion was then made that these movements were vibratory in character and had their origin in gusts of wind acting against mountain-ranges, and on the surface of the country over which they passed, and were then transmitted through the surface of the earth to distant localities which it might often happen that the wind itself never reached. It was also shown that tremors occurred almost always whenever the point of observation was crossed by a steep barometric gradient, and although the Italian observations had not been examined either in connexion with distant winds or barometrical gradients, what was true for Japan appeared to be equally true for the Italian Peninsula.

In the following summary respecting the distribution of earth pulsations with regard to space and time, a few of the writer's observations during the past eight years will again be taken, but instead of considering the records as effects due to vibratory motions of an elastic medium, they will be regarded as pulsatory wave-like motions in the earth's crust, and the reasons for thus regarding them have been already stated.

1. Tromometric disturbances throughout a large area (in Italy at least) when plotted in curves to show monthly distribution apparently agree in the time of their maxima and minima.

2. The greater frequency occurs during the winter months. This is true for Japan and Italy, and it is at this season that we have the greater frequency of earthquakes, and speaking generally for Germany and England the greater number of colliery explosions. From an analysis of the investigations described by M. Chesneau, the writer would say that for the particular collieries where the percentage of gas in the returns was measured from June to the end of October, the gas seldom reached 1 per cent., whilst in November, December, February, and March it has usually been above 1 per cent. For the other months, January, April, and May, no returns are given. The data, such as exist, are sufficient to show that at this particular mine the escape of gas followed the winter rule. Whether this is a general rule it is not easy to determine. Another phenomenon following the winter rule suggested to the writer by his late colleague, Dr. C. G. Knott, is that during the winter months many areas in the northern and southern hemispheres are crossed by steeper barometric gradients than in summer. For Central Japan at least this is very marked. For example, reckoning the gradients in millimetres per 2 degs. of latitude or 120 geographical miles, the following gradients are found across Central Japan :—

	High Barometer.		Low Barometer.		Total Pulsations.
	Pulsations.	No Pulsations.	Pulsations.	No Pulsations.	
1885.					
January (from 16th)...	6	5	8	0	14
February ...	6	6	7	9	13
March ...	6	10	11	4	17
April ...	4	11	6	9	10
May ...	4	13	5	9	9
June ...	4	9	0	17	*4
July ...	1	16	3	11	4
August ...	2	13	4	12	6
September ...	3	13	6	8	9
October ...	5	12	5	9	10
November ...	3	12	8	7	11
December ...	—	—	—	—	—
1886.					
January (from 20th)...	1	2	4	2	5
February ...	3	10	13	1	16
March ...	6	8	8	3	14
April ...	13	2	13	2	26
May ...	5	8	4	1	9
Totals ...	72	150	105	104	177

II. Occurrence of tromometric movements in relation to barometric gradient. The gradients are indicated in millimetres per 120 geographical miles, this being a convenient distance to measure on the weather maps.

Gradient.	Pulsations.	No Pulsations.	Percentage of times when Pulsations were observed.
0 ...	2	8	20
1 ...	28	21	57
2 ...	42	52	44
3 ...	40	40	50
4 ...	22	3	88
5 ...	20	8	71
6 ...	5	0	100
7 ...	3	0	100
9 ...	1	0	100

These records embrace a period between January 20th and the end of May, 1886.

From Table I. we see that tromometric movements have been most frequent during the winter months, and although it has often happened that with a low barometer there were no pulsations, yet pulsations are more frequent with a low than with a high barometer. From Table II. we see that with a very high gradient pulsations always occur, and generally they are proportionately more frequent as the gradient rises.

* The barometer often very low, but no pulsations.

To this may be added the observation, that, for all intensities of wind (the scale being from 0 to 6—6 being a hurricane) the average gradient was steeper when pulsations occurred than when they were absent. Further, it may be added, that for low gradients when pulsations occurred, the movements were always very small, and it often happened that the low gradient was immediately preceded or followed by a high gradient. On the other hand, for high gradients the pulsations were always more violent.

Although pulsations appear to be closely related to the wind, that they are more closely related to the gradient will be seen by comparing the following table with the Table II., both tables referring to the same group of observations.

Wind.		Pulsations.		No Pulsations.		Percentage of times Pulsations were observed.
0	...	10	...	16	...	38
1	...	53	...	47	...	53
2	...	54	...	49	...	53.4
3	...	37	...	16	...	70
4	...	12	...	1	...	92

As confirming the results here given, reference may be made to the observations extending over longer periods of time, published by the author in vol. ix of the *Transactions of the Seismological Society*, and especial attention is drawn to a table which shows that tremors are at a maximum in the Italian Peninsula when the barometric gradient is steep, no matter whether the barometer be high or whether it be low.

Another investigation connecting tromometric disturbances with barometrical fluctuations, has revealed the fact that whenever there is a barometrical change of or more than 6 millimetres in 8 hours (which usually occurs with a falling barometer), pulsations are pronounced—earth pulsations may therefore be connected with the rate at which pressure changes.

When seeking a connexion between the wind, barometric gradients and ground movements, an observation that escaped the writer's attention until the present year is the fact that the velocity of the wind is often far from being proportional to the gradient. For example, with a gradient from S.E. to N.W. of 5.45 millimetres in Tokio and Central Japan, generally the wind may be indicated as 0, 1 or 2 (velocities of zero to 3.5 metres per second), while with a N.W. to S.E. gradient of 3 millimetres, there may be wind in Tokio and in Central Japan of 3 (velocities from 6 to 10 metres per second). Similar observations have been made in other countries, but the writer is not aware that the differences observed are so pronounced.

Although many years have been spent in investigating earth pulsations, much has yet to be done before we shall be able to formulate all the laws connected with these phenomena. Their occurrence is apparently more closely connected with the steepness of the barometric gradient than with any other phenomenon; but just as atmospheric disturbances depend upon the forms of isobars, the direction of their advance, the steepness of the gradient and the like, so may the varying disturbances of the earth's crust be explained by a similar complexity of causes.

6. THEORETICAL ASPECT OF THE QUESTION.

Because the differences in barometrical pressure are long-continued and are greater in winter than in summer, and also on account of the greater frequency of marked fluctuations in these stresses in the former rather than in the latter season, it does not seem unreasonable to determine whether variation in barometric pressure is not sufficient to account for the frequency of tromometric movement and escapes of mine gas, which, from the little information the author has been able to collect, appear to have their maxima at the same period.

Fortunately this question has already been partially answered by Prof. George Darwin, F.R.S., in his report to the British Association on the Measurements of the Lunar Disturbance of Gravity. One phenomenon affecting the measurements of this quantity is distortion of the earth's surface due to barometrical loads. Assuming a modulus of rigidity for the earth's surface at 3×10^8 (in grammes weight per square centimetre) and a maximum barometric grade of 5 centimetres or nearly two inches in 1,500 miles, Prof. Darwin finds that the ground would be 9 centimetres or about $3\frac{1}{2}$ inches higher under the barometric depression than under the elevation.

As the modulus of rigidity of the earth's surface is in all probability less than that of glass (or 3×10^8) it is likely that the value 9 centimetres or $3\frac{1}{2}$ inches is very much too small. Further, because the wave is long, even if the deflection amounted to double this amount, as Prof. Darwin suggests, its effects would be equally great in the deepest mines. This result certainly accords with the results of observations, which show that pulsatory movements are quite as clearly marked deep underground as they are upon the surface. As to whether this general bending of strata is likely to cause an outflow of gas is another consideration.

The complete solution of the problem is an extension of Prof. Darwin's work. Instead of determining the effects of a statical load, we wish to know the effects of a barometrical load which is moving, first with a velocity equal to that of the progression of a given isobar, and

secondly with an intermittent progression corresponding for example to the intervals between the gusts of wind in a gale.

After looking at a number of maps showing the tracks of barometrical depressions in England and Europe, it appears that an average rate at which a depression travels is about 20 geographical miles per hour, or say 34 feet per second. Although the rate is high, it is probable that a uniform surface with the rigidity of glass would quickly adjust itself to the load as it passed across the surface. If however the load is irregularly applied upon the surface, and the surface, owing to the varying character of its strata, is not uniformly elastic, it does not seem unlikely that the surface should be broken up into a series of irregular waves. It seems however unlikely that the ordinary rise and fall of the tide could do more than produce a general bending.

7. THE ESCAPE OF FIRE-DAMP IN RELATION TO BAROMETRICAL PRESSURE.

The following few extracts epitomized from the writings of M. Chesneau and the Report of the Austrian Fire-damp Commission, the writer assumes to be fairly representative of the experiences of those who have investigated the relationship between the escape of fire-damp and fluctuations in barometric pressure.

M. Chesneau, in the paper already referred to, gives an interesting summary of observations which have been made on the relationship between the escape of fire-damp and atmospheric pressure.

M. Le Chatelier, after a critical examination of the investigations made by Galloway between 1868 and 1873, arrives at the conclusions that it is doubtful if variations in atmospheric pressure have any relationship with the escape of gas.

Mr. Schöndorf, who made observations in the Saar Basin, concluded that barometric fluctuations directly affected the escape of gas from the goaf. M. Nasu, by carefully examining the gas issuing from a particular bed, found that it increased with a barometric fall; but, as pointed out by M. Chesneau, it is likely the increase may have been solely due to a greater escape from the area enclosed by stoppings rather than an increased rate of distillation from the coal.

The experiments of M. Hilt led to the conclusion that gas increased with a barometric fall, and *vice versa*, but the examination of M. Hilt's results by Messrs. Mallard and Le Chatelier showed that great barometric falls only correspond with the appearance of small quantities of gas, whilst in regions cut off from goaf the correspondence was barely evident.

In the case of one considerable fall, at one mine the gas decreased while at another it increased.

The conclusions arrived at by Mr. Köhler at certain mines in Silesia were as follows:—

1. The quantity of gas diminishes with a rise of the barometer, and *vice versa*.
2. The quantity increases proportionately to the rate at which the barometer falls, and *vice versa*.
3. The quantity of gas disengaged is not absolutely dependent on the height of the barometer.
4. If the barometer rises rapidly and after that very gently, or remains steady at its maximum, a small increase of gas takes place; inversely if it falls rapidly, and then gently rises or remains long at a minimum, a diminution in the quantity of gas commences.

The quantity of gas was determined by chemical analysis.

The closest agreements between barometric fluctuations and the disengagement of gas occur at the mines where the old workings cover an extensive area. Mr. Köhler also made experiments by hermetically sealing the downcast and producing a depression by the revolutions of a fan, with the result that the quantity of gas was considerably increased, even when there was no communication with the goaf.

From the researches of the Austrian Fire-damp Commission, in five districts not containing old workings, practically no connexion was observed between the liberation of fire-damp and fluctuations in barometric pressure. It was, moreover, shown by experiment that the gas was contained in the coal under considerable pressure (in one case as high as 9·2 atmospheres), from which it might be inferred that slight barometric changes would produce no sensible effect upon the escape of gas. It was also observed that the volumes of gas collected from boreholes did not vary with atmospheric pressure.

The gas coming from old workings closely followed the barometric curve.*

CONCLUSIONS.

The facts of chief importance now before us are as follows:—As a result of observations made with exceedingly light tromometers and delicate levels, and other instruments, like delicate balances, the writer concludes that areas of the earth's surface are at times thrown into a series of flat

* *Trans. Fed. Inst.*, vol. iii., page 534.

wave-like undulations. These disturbances are frequent in the winter months. They may occur either with a high or low barometer, but they nearly always accompany a steep gradient. Theoretical considerations indicate that such disturbances might arise from fluctuations in barometric pressure exerted over extended areas. From the little information at the author's command it appears likely that fire-damp escapes in greatest quantity when earth pulsations are most frequent, but as to whether the compression and extension by repeated bendings which are slight in depth but great in length, influence the escape of gas is a matter for speculation. From the last quotations, which may be amplified by appealing to the results obtained by other investigators we may conclude :—

1. That a local barometric fall is directly connected with the escape of gas from old workings and goaf.
2. That local barometric changes have at least in the majority of cases but little, if any, appreciable effect on the escape of gas from coal.

One means of testing the writer's views would be to determine whether the escape of gas from the coal at any mine shows a relationship to the barometric gradient existing at the time of observation across the district in which the mine is situated.

Assuming the author's investigations should meet with confirmation, it would seem that our coal-mining districts should have the same facilities for quickly determining barometric gradients, the varying forms of isobars and the like, as are afforded to the seaports. Each mine should be able to ascertain at any moment the gradient and its direction, measured over a length of, say 200 miles ; and in addition, a tromometer which will at any time show not only the range of the resulting pulsatory motions, but their direction should be consulted.

Neither earthquake instruments nor ordinary tromometers which continue swinging by their own inertia, and may show maxima of motion when the actuating cause is at a minimum, and which naturally tend to change their planes of oscillation, should be employed. The instrument recommended, although by no means perfect, is the one described in this paper, which, having extremely little inertia, roughly measures the tilting and also indicates the direction from which the displacement approaches.



Mr. C. DAVISON (Birmingham) wrote, it appeared to him that there were many facilities in England for carrying out the observations suggested by Prof. Milne, and it was extremely desirable that advantage should be taken of them. The instrument described by Prof. Milne was simple and could probably be made at small cost, but his remark that, after one or two swings, two of these instruments may disagree in phase, showed that their indications, though useful, could not be entirely trusted. Possibly, however, this defect might be remedied to a considerable extent by immersing the instrument in paraffin oil. He (Mr. Davison) believed that the instrument most suited for the purpose would be either Dr. E. von Rebeur-Paschwitz's horizontal pendulum or Mr. Darwin's new form of pendulum with double-suspension mirror. The latter will be described in the report of the British Association's Earth Tremor Committee for the present year. Dr. von Rebeur-Paschwitz has given an account of his horizontal pendulum and of the results which have so far been obtained with it in his valuable memoir, "Das Horizontalpendel, etc."* Both instruments are of great delicacy, and their employment in mines, where creeping has ceased to be perceptible, could hardly fail to lead to results of great value, and possibly of important practical application.

The PRESIDENT proposed and Mr. SPENCER seconded a vote of thanks to the author of the paper and to Mr. Horace Darwin for his kindness in attending and explaining the use of the tromometer.

The vote was accorded unanimously.

The PRESIDENT said they must pass a hearty vote of thanks to the Institution of Civil Engineers for the use of their rooms, and to the owners and managers of the works which had been so kindly thrown open to their inspection during the meeting.

Mr. A. SOPWITH (Cannock Chase) seconded the proposal, which was heartily approved.

Mr. HENRY LAWRENCE (Durham) proposed a cordial vote of thanks to the President for his services in the chair.

Mr. F. G. SHAW (London) seconded the motion, which was cordially adopted.

* *Nova Acta der Ksl. Leop. Carol. Deutschen Akademie der Naturforscher*,
vol. lx., No. 1.

The *PRESIDENT* said he was obliged to the members for their vote, but they had heard so much of him during the last two days that he would not say more now than that this had been, so far as he could see, a most successful meeting.

The meeting then terminated.

The following notes record some of the features of interest seen by visitors to works, which were, by kind permission of the owners, open for inspection during the course of the London Meeting on June 2nd and 3rd, 1893.

THE WESTMINSTER ELECTRIC SUPPLY CORPORATION.

The area served by the Westminster Electric Supply Corporation, Limited, extends from the Thames to Oxford Street, and from Whitehall westward across Belgrave Square. The district is served from three stations, marked by small black blocks on the annexed map. These are situated respectively in Millbank Street, on the river and just south of the Houses of Parliament; in Eccleston Place, near Buckingham Palace Road, and in Davies Street, near Oxford Street, and midway between Regent Street and Park Lane. The capacities of these stations, stated in candle power lamps, are as follows :—

Davies Street	...	...	...	84,000
Eccleston Place	...	...	...	42,000
Millbank Street	...	...	...	60,000
Total	...	...	...	186,000

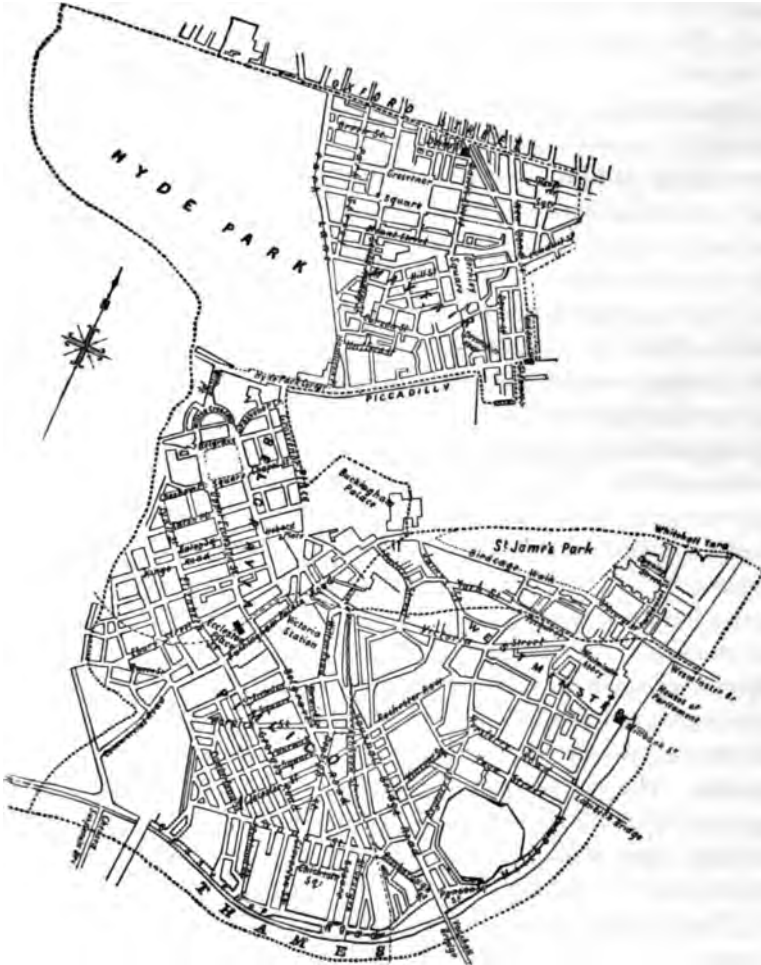
The number of lamps connected to each station may now (May, 1893) be stated approximately as :—

Davies Street	...	...	...	55,600
Eccleston Place	...	...	...	32,100
Millbank Street	...	...	...	21,000

Although the area is served from three centres, all the stations are connected to the general network of mains, and in slack times two stations may be shut down, leaving one to undertake the load.

The system adopted is low-tension direct-current distribution, with a battery connected to a battery, which not only aids the regulation, but supplies current in the night when the engines are stopped. The generators are wound to give a current of 220 volts pressure, and their terminals are connected across the outer mains. The current is distributed to the various parts of the network by means of feeder mains at a pressure of 100 volts, and on 100 to 101 volts in the distributing mains.

The street mains are laid wherever possible upon the Kennedy system. The culverts are formed of concrete. The carriers are of earthenware, and are let into the concrete, which is covered with bitumen to prevent damp. Copper strips are laid upon the supports, which are placed at intervals of 6 feet, so that no straining devices are needed as with the Crompton system. Where it is impossible to use culverts, Callender-Webber conduits, or cast-iron casings, are used, and where this is impossible iron-pipes are employed, into which the cables are drawn.



The price charged for the current was originally 8d. per Board of Trade unit. This was reduced to 7d. in 1892, and since March, 1893, has been further reduced to 6d., with a rebate to large consumers.

Prof. A. B. W. Kennedy, M. Inst. C.E., is the engineer-in-chief to the Corporation, and has designed the three stations, to which Mr. C. Stanley Peach, John Street, Adelphi, has acted as architect.

DAVIES STREET STATION.

The building in Davies Street is of a handsome appearance, and is several storeys in height, the ground floor being utilized for shops and the flats for residential chambers. Between these blocks of buildings is an open space in which is situated the engine-room, covered with a light roof. The chimney passes up the central space, independent of the walls of the building.

Great care was given to the construction of the engine-block which consists of concrete, 10 feet thick, isolated by 18 inches space from surrounding walls, and carries the entire range of engines and dynamos. Its lower surface is arched, and the rounded spaces are filled with sand to prevent the block from rocking. The chimney-base is at a lower level than the engine-base.

The ten dynamos are each driven directly by a Willans compound engine. Two are Crompton dynamos, each giving 450 ampères at 120 volts pressure, and driven by G G Willans engines. These machines are two-poled, and are used for balancing. When the loads on the two sides of the system are unequal, and there is a considerable current on the central or third wire, one of these machines is employed to redress the difference, and produce a balance. The two next dynamos are four-pole machines, built by the Electric Construction Corporation, each giving 300 ampères at 220 volts pressure. They are driven by H H Willans engines, having low-pressure cylinders 17 inches in diameter by 12 inches stroke, and running at the slow speed of 175 revolutions per minute. The four adjacent dynamos are two-pole machines, also built by the Electric Construction Corporation; they are driven by I I Willans engines, running at 350 revolutions per minute, the output being 500 ampères at 220 volts pressure. The two remaining dynamos are of the Crompton four-pole type, and of 112 kilo-watt capacity. A large steam dynamo, by Messrs. Latimer, Clark, & Muirhead, giving 1,000 ampères at 220 volts will be added during the summer.

The boilers are of a modified marine type, four being constructed by Messrs. Davey, Paxman, & Co., of Colchester, and two by Messrs. Fraser & Fraser, of Bow. Each boiler is 8 feet in diameter by 12 feet long, and contains two furnaces 2 feet 8 inches in diameter, crossed by two Galloway tubes. There is a dry combustion-chamber at the back of the boiler, into

which the gases are delivered previously to their passing through the 92 3 inches tubes, which lead them back to the smoke-box over the furnace fronts. The gases then flow into capacious side and bottom-flues, and thence into the main flue, which runs underground between the two rows of boilers. This flue delivers into the chimney, which is 180 feet in height from the firing level. There are six boilers already installed, a seventh will be put in during the summer, and space is left for three others. One special advantage of this type of steam generator arises from its shortness, which enables it to be got into and out of cramped premises with comparative ease, and it can be used in circumstances where the Lancashire boiler would be quite inadmissible.

The boilers are fed by two Pearn quadruple-acting pumps with $3\frac{1}{2}$ inches plungers, and one with $4\frac{1}{2}$ inches plungers. The feed is pumped through two Berryman heaters situated at the end of the row of engines, where the temperature is raised to 200 degs. Fahr.; and the exhaust steam can be directed entirely up the chimney, or wholly through the feed-heaters, or in any proportion desirable, by one large sluice-valve situate in the main exhaust pipe. The exhaust pipe is led up the centre of the chimney to within a few feet of the top. To guard against the machines being damaged by lightning passing down this pipe, there are two lightning conductors, and the pipe itself is most carefully connected to earth, so that a flash may pass off innocuously, and not damage the coils of the dynamos. The 8 inches steel steam-pipes are in duplicate in the boiler-house, and the engine-room steam-pipes will soon be complete in a ring. By this arrangement leaky joints can be dealt with at any time, without stopping the engines. The coal enters by the roadway, and there is considerable storage-room for it in cellars under the pavement and adjoining the boiler-house. A small tramway is provided for its distribution.

There is a voltmeter between each pair of engines to regulate the pressure, connected to a distant feeder. Supposing one engine to be running and the demand to be increasing, the regulator is opened wider and wider to keep up the pressure until the full power of the engine is reached. Then the second engine is started, and the same plan followed until it is fully loaded. The third engine is then started, and so on. When the load is decreasing, the engines are slowed down, and stopped one by one in the inverse order. From the distant end of each pair of feeders, wires are led back to voltmeters, to show the pressure in various parts of the network.

Automatic cut-outs are used to prevent the battery discharging back through a dynamo, in case the engine should stop. By means of magnetism induced by the current flowing through a coil, a heavy handle is held up;

if the current dies away the handle is released and falls, and in so doing operates a switch to break the circuit.

It is barely two years since the station was first started, and already it is so successful that 10,000 lamps have been fed from it at one time.

Mr. L. L. Foster, Assoc. M. Inst. C.E., is the resident engineer.

ECCLESTON PLACE STATION.

The site of the station at Eccleston Place is the largest of the three generating-centres; it is situated near Victoria Station, and a little north of Buckingham Palace Road. The Underground Railway passes the block, and the necessity of building part of the station over the tunnel added considerably to the difficulties of both architect and engineer. The store-rooms are all placed upon the ground-floor and basement at this end of the building, and the upper floors are occupied by the offices of the company, and the rooms of the resident engineer Mr. C. O. Grimshaw.

The total area which belongs to the company measures approximately 224 feet long by 101 feet wide, and of this rather more than half is now covered by buildings. Two main entrances are provided, so that coal-carts will enter at one door, pass on to a weighbridge, the coal will then be discharged into the stores in the basement, and the empty carts will pass out by the second door. Tram-lines are laid in all the passages, so that the coal is easily brought to the boiler-house. It is possible to store at least 300 tons at one time.

The boiler-house is below the ground level, and at present four boilers are installed; three are of the marine type, built by Messrs. Davey, Paxman, & Co., of Colchester, two are 12 feet long by 8 feet in diameter, the third is 10 feet 8 inches long by 9 feet in diameter, and the fourth is by Messrs. Fraser & Fraser, also of the marine type, 13 feet long by 9 feet in diameter. The smoke-box front of the latter is not provided with doors, but opposite each tube is placed a plug, which can easily be removed so as to allow of the tubes being cleaned if necessary without stopping the boiler. The working pressure of all the boilers is 150 lbs., and the average coal consumption per unit generated during the last quarter has been $5\frac{1}{2}$ lbs. of Welsh coal, working condensing.

Water is supplied to the boilers by two Pearn feed-pumps, which take their water from the condenser hot-well or from tanks placed over the pump-room and pump it through two Green economisers placed in the main-flue. The feed-water is thus heated to about 150 degs. Fahr. The water consumption is measured by a Kennedy water-meter placed between the pumps and the economisers.

The engine-room is very lofty, and the walls are of white glazed brick, which give it a fine appearance. The office is placed in one corner, and next to it is a small testing-room. At one end of the room there are two Willans triple-expansion engines of the I I size, developing 200 indicated horse-power at a speed of 350 revolutions per minute, and each of these drives direct a Crompton four-pole shunt-wound dynamo, developing 500 ampères at 225 volts. The armatures of the dynamos are wound with stranded cable pressed into a suitable rectangular form. Both of these engines are fitted with the Willans and Robinson special cooling apparatus, consisting of pipes placed inside the crank-chamber in such a manner as to allow of cold water being passed through them, and it is possible to run the engines constantly without overheating the bearings. Nearer the centre of the room are placed two sets, each consisting of a Windsor high-speed vertical compound engine of the inverted open type, by Messrs. Davey, Paxman, & Co., of Colchester, and a dynamo. They are fitted with a Paxman patent automatic expansion-gear and adjustable high-speed governor, by means of which the cut-off can be varied from zero to five-eighths of the stroke. A heavy fly-wheel, $6\frac{1}{2}$ feet diameter, and weighing two tons, is placed upon the end of the shaft opposite to the dynamo. The dynamos are of the Crompton four-pole type alluded to above, and develop 250 ampères at 220 volts. Two other small sets are placed in the corner of the engine-room; each consists of a Willans compound engine of the G G size, giving 80 indicated horse-power at 430 revolutions, with steam at 150 lbs. pressure. These drive direct two Siemens dynamos, each developing 400 ampères at 100 volts, but they can be run at a higher speed, and give 300 ampères at 135 volts for battery charging. These small dynamos are used for balancing.

A new dynamo of 500 ampères and 225 volts, by the Electric Construction Corporation, coupled to an I I Willans engine will be added during the summer.

The cables are carried from the machines inside bent gas-pipes embedded in the foundations, and thence up the walls.

The foundations for all the sets consist of one large concrete block 10 feet thick, which is perfectly free from the walls of the building, so as to prevent vibration of the structure. A 6 tons overhead crane serves the whole of the engine-room.

The steam-pipes will eventually be arranged upon the ring system entirely round the engine-room, and at present are provided with stop valves, so as to cause as little hindrance as possible in case of accident. The spindles of the valves are vertical, with hand-wheels below, and the

latter are cast in the form of a bowl, so that all the leakage is collected and may be run off by means of a small cock. The main steam-pipes, of steel, 8 inches in diameter, are fitted with wrought-iron screwed flanges. The copper branch-pipes are 5 inches in diameter.

The exhaust steam from the engines can either escape up the chimney, which is 150 feet in height, having a 21 inches cast-iron exhaust-pipe up the centre, or can be condensed. A large surface condenser, constructed at the Central Marine Works, Hartlepool, is placed in a space between the engine-block and the wall, about 10 feet below the engine-room level. It has 1,940 three-quarter inch tubes, 10 feet 6 inches long, giving about 4,000 square feet of cooling surface. The air-pump has a plunger 18 inches in diameter and 20 inches stroke, working horizontally, and driven by a connecting-rod from a compound vertical engine, with cylinders $6\frac{1}{4}$ inches and 17 inches in diameter and 15 inches stroke.

The switch-board, constructed by Messrs. Crompton & Co., consists of nine slate panels, and is a plug board. The regulating switches for controlling the charge and discharge of the cells are designed in a circular form. Each panel carries connexions for three machines and four feeders. That at the centre has at the top a pair of balancing switches, so that either of the 100 volt machines may be connected to either side of the three-wire system. Underneath these are placed two voltmeters, that on the right giving the volts at the terminals of each battery separately by means of wall-plug connexions, that on the left giving the total volts of the two batteries in series. The plugs at each side connect the dynamos to the batteries. There are two voltmeters below for the small machines, two ammeters, two field-magnet resistance-switches for the small machines, and two automatic gravity-switches for breaking circuit to the batteries when the dynamos are slowing down.

The next panel on the left, which is the negative side, carries a large regulating-switch at the bottom for a battery of fifty-six cells, and above it a large ordinary switch. The next panel to the left carries three automatic gravity-switches at the bottom, and an ampère-meter for each machine next above. The bars above these instruments contain plug holes, and are connected to the omnibus-bars at the back of the board. Four voltmeters for the pilot wires are above these, then the feeder-bars, and higher up the four ammeters for the feeders, each reading up to 500 ampères, while at the top are placed the main fuses, consisting of ten wires soldered to copper ends; and duplicate fuses are so arranged that in case one is melted another can be instantly switched into the circuit. The next panel is similar. The panels upon the right of the centre carry the

positive terminals, and are duplicates of those at the left, except that at the bottom are placed the field-magnet resistance-switches, and above these the three voltmeters for the difference of potential between the terminals of the dynamos. The joints are oval flanges of gun-metal, screwed and brazed upon the copper bars forming the mains. The flanges are carefully faced, and drawn together by bolts and nuts. Throughout the station the negative wires are all coloured red, the positive black, and the intermediate wires black and red in alternate rings. This colouring is the contrary of that used by some other companies, but Wilkes pole-finding papers are used for testing, and as these turn red when touched by the ends of the negative wire, it is easier to remember which is the positive and which the negative main.

The main conductors in the engine-room consist of round copper bars, which are carried along the walls and supported upon wooden brackets, and glass insulators and supports of notched fibre. Two Aron electricity-meters, with the Miller reversing arrangement, are placed in the battery mains. An ordinary Aron meter is used for the station-lighting circuit, supported away from the wall, hexagon unions being used for the joints of the conductors. Each dynamo is provided with an Aron meter. The engine-room is lighted by two Edison-Swan lamps of 200 candle-power, and small lamps are used for the switchboard.

The battery-room is upon the first floor over the boiler-house, containing two batteries of the Crompton-Howell type, each consisting of fifty-six cells containing sixty-one plates. They have been discharged at the rate of 800 ampères per half-hour, although their stated capacity is only 500 ampère-hours. The cells are supported upon wooden shelves resting upon iron columns, and the floor is of asphalt. Four extra cells in each battery are used as milking cells, in order to rectify any extra loss in other cells.

The third central station, situated in Millbank Street, Westminster, supplies the Houses of Parliament and the important district including the Government Buildings in Whitehall, and Victoria Street as far as Victoria Station.

GAS LIGHT AND COKE COMPANY.

Beckton, or "Beck Town" (so called in honour of a former governor of the Gas Light and Coke Company, the late Mr. Simon Adams Beck) is situated in the Essex marshes at a point towards the lower end of Galleons Reach of the River Thames, and about ten miles east of London. The

company's old works, lying almost in the heart of London, did not admit of extension ; and when larger premises became necessary, it was considered that the cost of coal delivery might be greatly reduced if the works were removed some distance lower down the river, so as to avoid the expense of barging and cartage ; while at the same time, by having plenty of land, there would be ample space for the storage of such residuals as coke, tar, and ammoniacal liquor. The present site having been secured, the first pile of the new works was driven on November 19th, 1868, in an uninhabited marshy swamp ; the works were put in operation on November 25th, 1870 ; and with the extensive additions made since that date Beckton may now be described as a town in reality, as well as in name.

The pier forming the approach to the works from the river is a wrought-iron structure supported on cast-iron cylinders, having a frontage parallel to the river of 800 feet, and projecting forwards 400 feet from the shore into the river. It affords berthing accommodation for four steam-colliers of the largest size ; and for discharging their cargoes each berth is provided with three steam or hydraulic cranes and a movable steam-crane : the unloading power being fully equal to 12,000 tons in twenty-four hours. There are two jetties, and, in addition, ample quay accommodation for smaller craft. An additional pier, with connecting viaducts and railways, equal in size and capacity to the existing one, is in course of erection.

On reaching the shore, the pier joins a viaduct on the same level and forming a continuation of it. At the point of junction four branches start from the main viaduct, two running along the right-hand side through a series of six retort-houses, and two along the left-hand side through a similar set of six retort-houses. The main viaduct, which has a double line of rails, runs along the whole length of the space between the two sets of retort-houses, a distance of three-quarters of a mile from the river to the end.

The retort-houses are all very much alike. The largest is 510 feet long by 100 feet wide, and is capable of producing $5\frac{1}{2}$ million cubic feet of gas per day. Running through the house on either side are high and low-level railways of standard gauge ; the high-level railway is used for conveying coals from the steamers alongside the pier to the coal-stores within the house, and the low-level railway is used for taking away the coke drawn from the retorts. Locomotives and iron wagons are employed on these railways. In the largest house there are forty-five beds, each containing nine fireclay retorts of 20 feet length, making a total of 405 retorts. Each retort-house has a complete set of purifying and other

plant attached to it; so that the Beckton works may be said to be made up of fourteen complete gas works, the smallest of which is of no mean calibre.

The coals are delivered into stores which are conveniently placed in the retort-house, so that the retorts may be readily charged from them. Each retort is charged with about 6 cwts. of coal every six hours. The mouth-pieces of the retort are securely closed up with iron lids. The gas as it is distilled from the coal passes up through vertical pipes, fixed at each end of the retort, into a long wrought-iron vessel, rectangular in section, placed on the top of the retort-beds, called the hydraulic main; its principal purpose is to serve as a self-acting valve for shutting off the gas when the mouthpieces are opened for charging and discharging the retorts; and it is also here that a large proportion of the tar is thrown down, and some ammoniacal liquor. When a charge is burnt off, the lids are opened, and the remaining coke is drawn out and deposited on the floor beneath the charging-stage. A portion of the coke is used for keeping up the heat of the retorts, and the remainder is loaded into wagons and taken away for sale.

The gas is withdrawn from the hydraulic main by exhausters, and is next passed through a series of horizontal cast-iron pipes 12 inches in diameter, called condensers, around which the air is allowed to circulate freely. In this apparatus the tar and ammonia travelling with the gas from the retort-house are condensed, and are run off into storage-tanks.

The gas issuing from the condensers is still very foul, for although nearly all the tar is eliminated, it still contains a considerable quantity of ammonia, carbonic acid, and sulphuretted hydrogen. To absorb these it must be propelled through washing or scrubbing-vessels. The scrubbers are generally in the form of circular towers, about 60 feet high, constructed of cast-iron plates, and filled with coke broken to a convenient size; brushwood is placed on the top to act as a distributor for the liquid. The foul gas entering at the bottom of the scrubbing tower and ascending through the coke is met by weak ammoniacal liquor or clean water percolating through the fine interstices of the brushwood, whereby the whole of the ammonia remaining in the gas is absorbed: and the combination is ammoniacal liquor, with which some carbonic acid and sulphuretted hydrogen are also taken up.

The gas has next to pass through eight purifying vessels in the following order:—First, through two vessels containing clean carbonate of lime, which removes the whole of the carbonic acid left in the gas; next through two vessels containing oxide of iron, which cleanses it of sulphuretted hydrogen; thirdly, through two vessels of lime that has been

previously sulphuretted, which removes the greater part of the bi-sulphide of carbon; and finally through two more vessels charged with clean lime, by which all traces of sulphuretted hydrogen are eliminated. The gas being now as pure as it is possible to make it, and of the required illuminating power, is in a fit state to be delivered for consumption; but before this is done, it is first measured through large station-meters, and stored in gas-holders, from which it is pumped out as required. For this purpose there are nine gas-holders at Beckton,* from which, by means of twelve large Beale rotary gas-exhausters (eight capable of pumping 250,000 cubic feet, and four 350,000 cubic feet per hour, making a total of 3,400,000 cubic feet per hour), the gas is propelled along two cast-iron mains 48 inches in diameter, from Beckton to Westminster, picking up from other stations on its way, and filling up other gas-holders along the line of route.

It may be mentioned that the company have eleven manufacturing stations in all, situated in various parts of the metropolis and suburbs; and the quantity of coal carbonized annually is about 2 millions of tons, of which about one-half is consumed at Beckton alone.

MESSRS. MAUDSLAY, SONS, & FIELD, LIMITED.

The following work was seen in progress:—

Single-screw engines for H.M.S. “Monarch,” of 8,000 indicated horse-power, having a high-pressure cylinder 49 inches in diameter, intermediate 74 inches in diameter, and low-pressure 112 inches in diameter, and 4½ feet stroke.

Twin-screw triple-expansion engines of 3,500 indicated horse-power for H.M.S. “Dryad,” building at Chatham, having cylinders 22, 34, and 51 inches in diameter, and 1¾ feet stroke.

Twin-screw triple-expansion engines of 5,000 indicated horse-power, for the Russian cruiser “Admiral Oushakoff,” building at the Baltic iron shipbuilding yard at St. Petersburg. The cylinders are 31, 46, and 68 inches in diameter and 2¾ feet stroke.

Three sets of single-screw engines for first-class torpedo-boats, built by Mr. White, of Cowes, for the Admiralty.

Single air-compressors for compressing air for the torpedo service on shipboard.

Also sundry small engines and gear in connexion with the foregoing work.

* The largest of which is of a capacity of 8 million cubic feet.

NORTH OF ENGLAND INSTITUTE OF MINING AND
MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD IN THE WOOD MEMORIAL HALL, NEWCASTLE-UPON-TYNE,
JUNE 10TH, 1893.

MR. J. B. SIMPSON, PRESIDENT, IN THE CHAIR.

The SECRETARY read the minutes of the last General Meeting, and reported the proceedings of the Council at their meetings of May 27th and of that day.

The SECRETARY read the Balloting List for the election of officers for the year 1893-94.

The following gentlemen were elected, having been previously nominated :—

MEMBERS—

- Mr. H. M. BECHER, Mining Engineer, 9, D'Almeida Street, Singapore.
Mr. J. C. S. BEYNON, Civil and Mining Engineer, P.O. Box 1364, Johannesburg, Transvaal.
Mr. GEORGE DAVEY, Mining Engineer and Metallurgist, Ferro-carril Michoacan y Pacifico, Maravatio, Mexico.
Mr. STANLEY H. FORD, Mine Agent, Stolzenfels, Great Namaqualand, South Africa.
Mr. THOMAS GILCHRIST, Mining Engineer, Manor House, Penshaw.
Mr. GEORGE LINDAY, Colliery Manager, Blackett Colliery, Haltwhistle, Northumberland.
Mr. WILLIAM ERNEST LISHMAN, M.A., Viewer, Bunker Hill, Fence Houses.
Mr. J. S. QUIRK, Metallurgist, St. Helens Lead Smelting Works, St. Helens, Lancashire.
Mr. F. GEORGE SHAW, Mining Engineer, London.
Mr. EDMUND SPARGO, Mining Engineer, 3, Cable Street, Liverpool.
Mr. CHARLES ROBERT WESTERN, Engineer, Broadway Chambers, Westminster, London, S.W.
Mr. JOSEPH HENRY WOOLCOCK, Civil and Mining Engineer, 49, Lowther Street, Whitehaven.

ASSOCIATE MEMBERS—

- Mr. G. A. FERGUSON, Editor of the *Mining Journal*, 18, Finch Lane, London, E.C.
Mr. HENRY M. JAMES, General Manager, Colliery Office, Whitehaven.
Mr. HARRY PAGE WOODWARD, Government Geologist, Perth, Western Australia.

ASSOCIATES—

- Mr. JAMES BAINBRIDGE, Under Manager, North Walbottle Colliery, Newcastle-upon-Tyne.
 Mr. ROBERT EMERSON, Engineer, Tudhoe Colliery, Spennymoor.
 Mr. ALEXANDER A. JAMES, Under Manager, Croxdale, near Durham.
 Mr. JOHN W. THOMPSON, Colliery Surveyor, Backworth Colliery, Newcastle-upon-Tyne.
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The following gentlemen were nominated for election :—

HONORARY MEMBER—

- Professor JOHN HERMAN MERIVALE, Professor of Mining, Durham College of Science, Newcastle-upon-Tyne.

MEMBERS—

- Mr. ARCHIBALD THOMAS BROWN, Mining Engineer, 372, Flinders Lane, Melbourne.
 Mr. WESTGARTH FORSTER BROWN, Mining Engineer, Alston House, Parade, Cardiff.
 Mr. RICHARD ECK, Mining Engineer, Beaconsfield, South Africa.
 Mr. JOSEPH GOULDIE, Mining Engineer, Kimberley, South Africa.
 Mr. JOSEPH HARGREAVES, Colliery Manager, Gwaun Cae Gurwen Collieries, Brynamman, R.S.O.
 Mr. JOHN HOLT, Jun., Civil and Mining Engineer, The Hollies, Heywood, Lancashire.
 Mr. EDWARD HOPPER, Engineer, c/o Messrs. Lewis & Marks, Coal Mines, Vereeniging, Transvaal.
 Mr. JOHN WILSON RICHMOND LEE, Mining Engineer, Potes, Provincia de Santander, Spain.
 Mr. J. B. ROBINSON, Mining Engineer, Hedley Hill Colliery, Waterhouses.
 Mr. WALTER ROWLEY, Mining Engineer, 20, Park Row, Leeds.
 Mr. THOMAS BIRCH FREEMAN SAM, Mine Manager, Adjah Bippo, West Coast, Africa.
 Mr. JOSEPH SCOTT, Mining Surveyor, Newcastle Street, Stockton, near Newcastle, New South Wales.

ASSOCIATE MEMBER—

- Mr. GEORGE THOMAS DUNCAN, Engineer and Agent, 110, Dilston Road, Newcastle-upon-Tyne.

ASSOCIATES—

- Mr. EVAN COCKBURN, Back Overman, Page Bank Colliery, *via* Willington, Co. Durham.
 Mr. WILLIAM HENDERSON, Engineer, Wheatley Hill Colliery, *via* Trimdon Grange.
 Mr. MOSES HOBSON, Under Manager, Shildon, *via* Darlington.
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Mr. EDWARD HALSE read the following paper on "The Gold-bearing Veins of the Organos District, Tolima, U.S. Colombia."

THE GOLD-BEARING VEINS OF THE ORGANOS DISTRICT,
TOLIMA, U.S. COLOMBIA.

BY EDWARD HALSE.

INTRODUCTION.

Organos is a small Indian village lying in a valley near the pass of Chiflón,* one long day's mule-ride south-west of Aipe, and about the same distance north-west of Neyva—both towns on the upper Magdalena river. Savanilla is the port for this river, which runs between the eastern and central cordilleras of the Andes northward to the Caribbean Sea. The Magdalena river is navigable for light-draught steamers as far as Honda (650 feet above the sea), where the first rapids are met with, a distance of about 550 miles from the coast. Above Honda smaller steamers ascend to Girardot, the port for the capital, Santa Fé de Bogotá (8,300 feet) on the eastern side, and for Ibagué (4,300 feet) on the western side; and, during the wet season, to Neyva (1,200 feet), about 700 miles in the interior.

The Andes in Colombia are divided into three ranges or cordilleras. These are spread out considerably northward, but run close together to the south. The central cordillera is *par excellence*, the metalliferous one. The mines of the Organos district are situated on its eastern flank. To reach these from the Magdalena river one has to cross the Chiflón Pass over a singularly bold and serrated range running north-and-south to the west of Aipe and Neyva. The range, rising from 7,000 to 8,000 feet above sea-level, is composed of highly-inclined beds of a hard red conglomerate alternating with sandstone, whose trend is parallel to the axis of the range, and whose dip is eastward. The formation is said to be of Triassic age.

Owing to the hardness of the rocks and the steepness of the mountain-sides, the road over the Chiflón Pass is one of the worst in Colombia, bad as

* A *chiflón* is (1) stagnant water into which a stream falls with noise; (2) a wooden pipe or flume; (3) a mining term, *trabajar chiflón*, is work making way in length and depth.

the roads of that country generally are ; and mules laden with cargoes not infrequently slip down the western slope, and are lost in the ravines below. From the top of the Chiflón Pass a splendid view of the surrounding country is obtained. Eastward one looks down the forest-clad side of the mountain, dotted below with magnificent royal palms (*palmas reales*) and other tropical trees, across wide plains down the centre of which the Magdalena river winds, until the eye rests upon the eastern Andes, blue and hazy in the distance. Westward the topography is entirely different. In this direction one looks upon a sea of almost treeless hills, backed by forest-clad mountains towering one above the other, the whole forming part of the eastern flank of the central cordillera. The hills in the foreground, covered only with grass and small shrubs (except in the valleys and gullies, the lower portions of which are more or less densely clothed with vegetation) form steep and narrow ridges, trending north and south, flanked by knife-edged cordons or ribs (*cuchillos*) oblique or perpendicular to them, which in their turn are strongly ribbed in a direction perpendicular to their length. Thus between the ranges are narrow winding valleys or *cánadas*, down the moderately-sloping bottom of which a river or strong stream of water usually courses, and between the lateral cordons are steep gullies or *quebrados* opening into the valleys on either side, down which torrents of water flow in the wet season.

The formation consists of crystalline eruptive rocks and metamorphosed schists. Of the former granophyre,* felsite, and hornblende-dolerite, in bedded masses and in dykes, predominate. The granophyre and felsite are generally moderately hard, and of a pale green colour. They are in places stained red with oxide of iron, and are frequently altered to a soft white clay resembling kaolin. The dolerite is usually very hard, and of a darker green—in places this rock too is soft and decomposed, but it usually retains its colour. Wherever observed it is strongly charged with iron pyrites. It is chiefly from the rapid erosion of some of the beds that the hills derive their peculiar topography.

The metamorphic rocks, usually consisting of chloritic schists and slates, are seen at the base of some of the hills, and form the major portion of others.

The schistose rocks in the State of Tolima have been variously described

* A mixture of orthoclase-felspar and quartz which have simultaneously consolidated. These rocks in the Organos district were formerly called sandstone. Sections cut of typical specimens of the country have been examined and named by a well-known petrologist. Some exhibit beautiful examples of the structure known as granophyric.

as of Silurian, Cambro-Silurian, and Laurentian age. These and the eruptive rocks overlying them are most probably Palæozoic, but so far in sufficient data have been collected to determine their exact age. It appears that when the central cordillera was upheaved at the close of the Triassic or commencement of the Jurassic epoch, these beds, breaking through the Triassic sandstones overlying them, were forced up to the surface, and were considerably contorted during the process. The formation in places exhibits evidence of a good deal of confusion; the strike and dip of the beds vary considerably, and at short intervals; they are also much jointed and fissured, and are moreover permeated by felsitic dykes.

Here and there in the eruptive rocks are lenticular masses of schistose rocks, and the former appear to merge imperceptibly into the latter, so that possibly the rocks called eruptive are the result of extreme metamorphism of sedimentary rocks brought about by long-continued pressure, heat, and aqueous action.

A number of veins have been found traversing the rocks in various directions—the prevalent one being nearly east and west—and containing quartz with visible gold associated with manganese and oxide of iron near the surface, and with iron pyrites, galena, etc., below. The gold above the water-level is extremely patchy, and visible gold is by no means the sign of a rich vein, for it is seen here and there in veins whose average only runs a few pennyweights to the ton. Some of the veins run into and continue through the schistose rocks, and appear to be of more stable nature therein. Some veins are very rich, especially at and near the surface, carrying gossan with from one to several ounces of gold to the ton for a certain distance, which seldom amounts to many yards either in length or depth, and then a fresh vein has to be sought elsewhere. Mining in this will-o'-the-wisp style was carried on for some years, and has only recently given place to something approaching to system; but as the water-level has not yet been reached, the problem has still to be solved whether the veins are sufficiently auriferous to be worked profitably for any long period of time.

So far as the writer is aware, a description of this district has never yet been published. Señor Vicente Restrepo, in his very interesting work* on the Colombian mines, mentions only the fact that numerous gold and silver veins occur here, and that in Constancia one only was then being worked containing rich ore, but scarce.

* *Estudio sobre las minas de oro y plata de Colombia*, second edition, 1888, page 99. Translations of this work have appeared in English and French.

The veins may be classified as follows :—

1. Bedded or segregated veins (*Lagergänge*) of rich auriferous quartz or gossan.
2. (a) Veins of rich auriferous gossan } Usually of shallow depth
 (b) Veins of rich auriferous quartz } and uncertain length :
 they may be termed
 superficial fissure-veins.
3. Auriferous flucany joints.
4. Quartz fissure-veins carrying free-gold near the surface, and auriferous pyrites below.

Classes 1, 2, and 3 generally occur in the eruptive rocks only, while class 4 occurs both in the eruptive and sedimentary rocks beneath or adjacent to them.

1.—AURIFEROUS BEDDED VEINS OR SEAMS.

Typical veins of this class are seen at the Chorro working of the Constancia mine, where a big open cut has exposed several of them, and from which a fair quantity of gold has been raised. Fig. 1, Plate IX., is a section of one of these auriferous quartz-seams which, at the point examined, is from 6 to 18 inches thick, and suddenly changes in dip from almost horizontal to nearly vertical. It appears to be in reality a somewhat complex case of a saddle-reef. The country here is decomposed granophyre stained with iron and manganese, some of whose layers are seen to end abruptly against one wing or leg of the saddle. Such contortions are local in character, and the veins much more frequently have the appearance of Figs. 2 and 3, Plate IX. In the former case the vein is about 1 foot wide, consisting of quartz in two layers lying on a thin stratum of rock veined with quartz, oxide of manganese, and ochre. The true floor is altered, ochre-stained granophyre, while the roof is still softer, being composed of ochreous and manganiferous clay.

The quartz-layers are apt to merge suddenly on either side into rock, leading to the inference that they were formed by replacement. The quartz contains iron pyrites in its cavities, and sometimes clay and gold, as well as blende and galena stained with oxide of iron. The gold in these seams is generally visible, and sometimes coarse. It is irregularly distributed, and some very rich specimens can be found.

The bedded veins run from nearly east and west* to a little west of north, and dip about 60 degs. south or west respectively (variation 43 degs.

* All bearings magnetic, 1888.

to 70 degs.). The direction of one bed here is north 35 degs. east to south 35 degs. west (dip south-east 43 degs.), which is nearly normal as regards both strike and dip.

A slickenside joint clearly marked, being stained with black oxide of manganese, is sometimes visible in the clay forming the roof (Fig. 3, Plate IX.). It was noted that the lines are not parallel with the dip, but make an angle of about 10 degs. with it, and also that in places there is a want of parallelism among the lines themselves. The seams are crossed perpendicularly by some joints also showing slickensides. As will be seen from the section (Fig. 3) the country adjacent to or separating the quartz-layers is decomposed to a clay.

In places the rock shows evidence of a schistose structure, but this matter will be referred to again when treating of veins of class 2.

At the Silencio mine at least two bedded auriferous quartz-veins are seen to crop out on the face of a very steep hill. The lower one is the richer and can be traced for about 100 yards along the surface. The outcrops as exposed on the hillside form an angle of about 25 degs. with the horizon. The chief bedded vein runs about north $8\frac{1}{2}$ degs. west to south $8\frac{1}{2}$ degs. east, and dips west 30 degs. to $48\frac{1}{2}$ degs., or against the hill. The average width of the vein is 2 feet, but the rich auriferous quartz-leader is seldom more than 6 inches thick, the rest of the vein being composed of smaller layers of quartz divided by country. The quartz varies in structure from solid to sugary, and is spotted with iron pyrites, manganese, oxide of iron, clay, etc. Visible gold is of common occurrence in certain parts of the outcrop. In a piece of highly auriferous quartz a single crystal of hæmatite was found. The vein was sunk upon in one place—the dip changed from 30 degs. at the surface to $48\frac{1}{2}$ degs. below—the quartz quickly wedged out a few yards from the surface and with it the gold, giving place to a clay or flucan. The latter was followed down to a depth of about 100 feet on the dip, when the sinking was stopped, as no further ore had been met with. The veins vary in richness from about 3 dwts. to 3 ounces of gold to the ton, and are usually rich or poor on the same horizon.

At the Socorro mine a bedded vein has been partially worked, which in one place has the section shown in Fig. 4, Plate IX. It appears to be a trough or inverted saddle-reef. The quartzose seam merges in places into ferruginous rock, and some layers of the country with thin seams of quartz end abruptly against one wing or leg of the trough. In neither of the peculiar contortions figured is there evidence of a saddle or trough-joint.

2.—(a) VEINS OF AURIFEROUS GOSSAN.

At the Te Encontré* workings of the Constancia mine there are several examples of this class of vein in quartz-felsite. They are remarkable for their very singular appearance (Figs. 5 to 10, Plate IX.). They trend usually a few degrees north of east, and dip south, and, as a rule, are auriferous to no great extent either horizontally or vertically. They appear to be especially auriferous when crossing certain manganiferous, ferruginous, and ochrey layers of the country (Figs. 5 and 6), which strike a little west of north, or perpendicular to the veins, and against certain wedges or horses of schistose rock found in the felsite (Figs. 7 and 10).

The ore is generally gossan or earthy brown oxide of iron, which frequently contains visible gold. The centre of the vein is sometimes composed of crystalline quartz. The precious metal is also found in the manganiferous and ochrey layers on the sides of the vein, and even for some little distance therefrom. These veins are extremely irregular, having no defined walls, although generally a southerly dip is roughly traceable.

Immediately above the section shown in Fig. 7 is a layer of soft manganiferous rock 1 foot thick. In Fig. 8 the vein consists of a rich auriferous band of gossan from 12 to 15 inches thick. It is nearly vertical, the south wall being defined by a thin seam of clay or flucan, while no joint occurs on the north side. The vein in all has three nearly vertical seams of clay crossing others dipping flatly to the south; the latter appear to have slipped down a little on the south wall of the vein.

The felsite country rock often has a brownish mottled appearance. Under the microscope it is seen to be traversed by minute stringers of quartz.

At the Socorro mine some thin but extremely rich veins of this class have been met with, consisting of a few inches of light brown gossan showing visible gold in the broken surfaces and assaying 50 ounces of gold to the ton and upwards.

At the Silencio mine several veins of the same class occur in granophyre. One trends on an average east $13\frac{1}{2}$ degs. south to west $13\frac{1}{2}$ degs. north, and dips south 56 degs. to 68 degs. At the surface it is about 1 foot thick, with from 2 to 4 inches of brown gossan on the hanging-wall, the rest of the vein being soft altered granophyre with hard lumps of quartz, country, and oxide of iron here and there. Ten feet down the vein shows iron pyrites, with oxide of iron, and quartz in lumps. It was

* Literally, "I have found thee!" the exclamation of the miner who discovered the first rich vein in this district.

proved by a cross-cut driven in 20 feet vertically below the outcrop. When cut it was found to be disordered by a slide, and consisted of gossan and quartz with well-defined walls having a regular dip. The mineral showed visible gold, and gave an excellent colour in the batea. Westward it was split into two branches by a horse of rock—the branches together made 8 inches of rich gossan (Fig. 9). In this instance the country was intersected by joints more or less parallel to the vein, and dipping in the same direction at an angle of 45 degs. The ore in one spot made against a bed of dark stained rock (altered schist?) as in the Constancia mine (see Fig. 10, and compare Fig. 7). Westward the vein was cut out 24 feet from the cross-cut; eastward, although the joint was straight and well-defined, the vein 20 feet from the cross-cut consisted only of 4 inches of auriferous gossan. A second cross-cut was run in from the surface in order to ascertain if the vein went down. But nothing was cut, not even a pronounced joint, and yet the vein was traceable on the surface for about 100 feet in length.

2.—(b) VEINS OF AURIFEROUS QUARTZ.

At the same mine, a vein believed to belong to this class intersects the bedded veins of gold-bearing quartz already described as running north $8\frac{1}{2}$ degs. west, and dipping west. The vein trends north-east to south-west, dips south-east from 30 degs. to 50 degs., and consists of what is known locally as *formacion*, or country altered to a clay (the *cascajo* of Venezuelan, the *mullock* of Australian, and the *bluff* of American miners). At the junction it was 1 foot wide, and when driven on into the hill in a south-westerly direction the vein was double in size, and had much improved in value. Fig. 11, Plate IX., shows the appearance of the vein some little way in. The *formacion* here consists of decomposed granophyre, mottled red, yellow, white, and brown, and containing native gold in crystals. The quartz was fairly spangled with gold, almost every stone broken showing the precious metal; but very loose, and in exceedingly thin plates and fine grains. The gold was easily shaken out of the specimens, and appeared to have been deposited quite recently. A sample taken, not showing visible gold, gave 1 oz. 8 dwts. of gold to the ton. The decomposed rock in the vein gave a good colour in the batea.

Farther in the vein showed a tendency to split up (Fig. 12, Plate IX.), and was less rich. However, the vein has since been driven on for a length of 65 feet, the *formacion* carrying gold, and increasing in width with stringers of ore. A rise was put up 43 feet to the surface; for 28 feet

the vein was very rich in gold, and from $2\frac{1}{2}$ to $4\frac{1}{2}$ feet thick, the last 15 feet consisting of formation carrying gold and intersected with stringers of quartz to within a few feet of the surface.

The vein was sunk on 25 feet, the lode, including formation, was from 3 to $3\frac{1}{2}$ feet wide with solid quartz from 1 to 2 feet wide. For a time the lode improved in depth, every stone broken showing visible gold. Nevertheless the writer believes that eventually the vein gave out both in length and depth.

This vein, consisting as it does of quartz and altered rock (formation), and containing little or no gossan, seems to form a class of its own.

3.—AURIFEROUS FLUCANY JOINTS.

The only auriferous joints observed by the writer in this district are a few at the Socorro mine. These run east 19 degs. north to west 19 degs. south, and are vertical, or dip sharply to the south. The joints bear clay and native gold, but are auriferous to only a very limited extent. They possess features of no particular interest.

4.—AURIFEROUS QUARTZ FISSURE-VEINS.

These veins are found traversing the eruptive and metamorphic rocks indiscriminately. Two veins of this class cross the bedded veins of Chorro, one trends north-west with a high dip, is 27 inches thick, and consists of quartz, and red, yellowish, and black-stained rock; the other vein strikes east $22\frac{1}{2}$ degs. south to west $22\frac{1}{2}$ degs. north, and in one portion is filled with clay and oxide of iron rich in gold, while in another it is 2 feet wide, and is filled with quartz, clay, and iron pyrites.

At the Socorro mine one vein which has been proved near the surface for about 200 feet in length occurs in more or less altered granophyre. The average run of the lode is east 26 degs. north to west 26 degs. south, the average dip south 72 degs., and the average width 3 feet. The strike varies from east $16\frac{1}{4}$ degs. north to east $35\frac{1}{2}$ degs. north, the dip from 62 degs. to 82 degs., and the thickness from 4 inches to 6 feet. In the granophyre the contents are chiefly auriferous oxide of iron and quartz in leaders, separated by more or less altered rock (Fig. 13, Plate IX.).

About 100 feet below the outcrop the lode passes into hard hornblende-dolerite—possibly an altered schist; the dip changes from 72 degs. to 82 degs., and the lode is characterized by bands of iron pyrites, galena, quartz, and hard country rock—the latter either dead, or with some calcite, quartz, and iron pyrites. Each wall is marked by a well-defined ferruginous joint, but without any clay selvage. Fig. 14, Plate IX., shows

the structure. A joint or bedding-plane striking north-west, dipping south-west, and crossing the lode near the hanging-wall, is probably the feeder of the lode at this point. The country next to this wall is sprinkled with iron pyrites, and contains calcite in large crystals.

The mineral from this portion of the lode, hand-picked, yielded 6 ounces of gold to the ton and upwards, and paid to export to Swansea.

The trend of the lode in the moderately hard rock, and where rich, is east 17 degs. north—this is the useful bearing of the lode—but in very hard rock met with farther west the trend becomes more northerly or east 35 degs. north (angle of horizontal bending = $19\frac{1}{4}$ degs.), the dip changes to north 80 degs. (angle of vertical bending = 18 degs.), and the lode is impoverished. Furthermore, a cross-joint is met with here, which has the effect of cutting off the mineral contents almost entirely. Harder rock is met with in the stopes also in this direction, and the lode is poorer, but a few hundred feet farther west some rich quartz from 1 to $2\frac{3}{4}$ feet in width is found in the lode near the surface (rock : decomposed granophyre), where the trend and dip correspond to that of the richer portion of the lode in the dolerite.

A cross-cut driven north-west through the country in this part of the mine discloses purple beds of quartzose schists trending north-west to south-east and dipping south-west, followed by a dyke of hard dolerite dipping northward, which is succeeded by altered granophyre. Here and there also in the schists occur patches of the latter rock.

At Te Encontré, a lode has been proved for about 600 feet in length and 182 feet in depth in quartz-felsite. The average run of the lode is east 9 degs. north to west 9 degs. south, and the average dip south 63 degs. The angle of total divergence in strike is $31\frac{1}{2}$ degs., and in dip 49 degs. The average width was 5 feet, varying, however, from 6 inches up to 6 feet. In the No. 1 and No. 2 levels, the rock is quartz-felsite, often much altered, and the vein consists of ferruginous quartz with free-gold. In the No. 3 level, however, the rock is dolerite, which becomes very soft in the No. 4 or bottom level.

In No. 3, where the rock is moderately hard dolerite, the lode is about 6 feet thick, half of this being well impregnated with galena and iron pyrites, the latter being scattered all through the lode. The galena is argentiferous and carries some gold, but the iron pyrites is much more auriferous. The effect of a flucan crossing the lode in one of the stopes is to flatten it considerably (Fig. 15, Plate X.). At *a*, the vein was continued inside the clay flucan itself, as an irregular mass of auriferous

and ferruginous quartz. In the No. 4 level, or 182 feet from the surface (measured vertically), a cross-course has thrown the lode 110 feet to the north. On the west of the cross-course, the lode is $4\frac{1}{2}$ feet wide in a soft green rock with joints having polished surfaces (altered dolerite) sparsely sprinkled with iron pyrites. The dip is south 79 degs. The lode to the east of the cross-course is quartzose, from 12 inches to 2 feet thick, and poor in gold.

About 12 feet south of the western portion of the lode in No. 3, a vein of quartz 2 feet wide and dipping south is seen on the walls of the cross-course, and 24 feet farther south is another vein of quartz, somewhat auriferous. As these veins pass through the cross-course they would appear to be of more recent date than the latter.

Hence in this mine we appear to have evidences of:—

1. An older east and west fissure.
2. A newer north and south cross-course.
3. Newer east and west fissures.

About 200 yards east of this, a parallel vein was discovered of 2 feet of white sugary and friable quartz, showing here and there minute specks of native gold. Notwithstanding the favourable appearance of the quartz, the yield was only a few pennyweights to the ton. It was considered likely that most of the gold had quite recently been leached out of the vein.

At Silencio, a vein of this class, traceable for 600 feet along the surface, has been worked 400 feet in length at a depth of about 100 feet vertical from the surface. The average strike, dip, and width are east 29 degs. south to west 29 degs. north, south-west 62.5 degs., and 2 feet respectively. The rock on the 100 feet level is in the main hard granophyre. The lode was widest (4 to 6 feet) and richest when the strike was north $42\frac{1}{2}$ degs. west or north-west nearly, but to the north of this point a branch falls into the lode on the hanging wall, and near the centre of the run of ground, a non-auriferous quartz-vein trending nearly east and west and dipping south, crosses it obliquely. The lode was formed of one or more layers of quartz sprinkled with iron pyrites and galena, and showing here and there crystals of blende. The quartz was generally of somewhat transparent crystalline structure, occasionally sugary, and frequently stained red in the joints. It was colourless, or had a brownish tinge. Sometimes the quartz was light bluish. Here and there it contained visible gold, but the latter was no real indication of richness. The gold contents varied from a few grains to several ounces to the ton. A milling test of several hundred tons yielded about 4 dwts. to the ton,

and as 1 dwt. was found in the tailings, the average gold contents were only $\frac{1}{4}$ ounce to the ton.

Just beyond the point where the lode was widest it split up into two branches: that on the southern side consisted only of a few inches of unproductive quartz, while the northern branch consisted of about 6 inches of auriferous and pyritic quartz. The hanging-wall appeared to be a schistose rock, the footwall being brown granophyre. In some points the schistose rock was on the footwall, but it was more generally on the hanging wall. The leader sometimes lay on the hanging wall, but it was more often a little distance from it, and sometimes having a much flatter dip, it gave the lode a wedge-shaped appearance as seen in section. Figs. 16 to 20, Plate X., represent the appearances assumed by the lode in this part of its course. By comparing Figs. 16 and 17 (the latter is from a point about 1 foot north of the former) it will be seen that a band of rock highly charged with iron pyrites has become a band of quartz charged with the same mineral; this appears to be an instance of local replacement.

It has been observed that in certain districts galena is a good indication for gold.* In order to ascertain whether the galena contained the precious metal, the writer made (1) an assay of the quartz well spotted with this mineral, the result was 9 dwts. of gold to the ton; (2) an assay of galena carefully picked out from the quartz resulted in 45 ounces of silver and 2 dwts. of gold to the ton. As the concentrated sulphides in the vein yielded nearly 15 ounces of gold to the ton, the result was arrived at that the major portion of the gold is present in the pyrites, while some is undoubtedly free at and near the surface.

A long cross-cut was driven in to strike this lode at a depth of about 200 feet from the surface.

In the cross-cut, three hard bands of hornblende-olivine-dolerite were cut bearing iron pyrites alternating with granophyre varying from moderately hard to soft. The rocks appeared to be in beds from 3 to 20 inches thick, trending east 10 degs. south and dipping south 36 degs. to 53 degs. A few joints cut these beds striking north $22\frac{1}{2}$ degs. west to north-west, and dipping south 54 degs. Others ran east and west to east $22\frac{1}{2}$ degs. south, dipping north 51 degs. to 62 degs.

* "It is worthy of note that in this mine (Latham and Watson's quartz mine, on Hustler's Reef, Sandhurst) the gold is aggregated in cavities with the softer sulphides, such as galena, and is rather sparingly diffused in the laminae which enclose iron pyrites."—R. Brough Smyth, *Gold Fields and Mineral Districts of Victoria.*, 1869, page 329; see also footnote on same page. Galena is often associated with free-gold in the New Morgan gold-mine of Wales.

According to recently published reports, highly contorted ground has been met with just where the lode was expected to be cut, consisting of 9 feet of blue auriferous quartz and 15 feet of limestone-deposits (*sic*), the latter also carrying some gold.

In the north-western portion of the mine, the rock has a brownish mottled appearance; examined through a microscope it is seen to be granophyre spotted with chlorite (probably after biotite). In this section the veins bear very little gold.

In the same mine, a pyritous quartz-vein coursing through chloritic-schist was proved for about 135 feet in length. It trended on an average east 34 degs. south to west 34 degs. north. The filling was 18 inches of white quartz, well charged with iron pyrites, but the average assay value was only about 10 dwts. of gold to the ton.

On the opposite side of the river Chiquilá, several veins are seen trending through clay-slate rocks, some of which have been worked to a certain extent. In the bottom of the Arroyo del Muerto, separating the La Reina from the La Union claims, two veins appear to form a junction, V-shaped in plan. The easternmost of these consists of 8 inches of quartz sprinkled with sulphides. In a level 30 feet above, both the quartz and the country are loose in texture. The quartz is white, and in one leader 8 inches thick below, 7 inches in the middle, and 3 inches at the top of the level. The vein trends north-west and dips south; outside the level, the vein is split up and disordered. Higher up the hill eastward are two outcrops which appear to be continuations of the western branch of the same vein. The first and lower one is 9 inches thick of brown quartz dipping south 24 degs.; the second and higher one of similar quartz 6 inches wide and dips south 39 degs. A sample from these out-crops gave 9 dwts. of gold to the ton.

The westernmost vein runs east 10 degs. south to west 10 degs. north, and dips south 50 degs. on an average. The vein is traceable along the slope of the hill for a length of 300 feet, corresponding to a height of 160 feet vertical. At the top working, the vein consists of 6 inches of solid quartz dipping south 73 degs.; 50 feet below this point, the dip changes to south 47 degs., and the vein averages 10 inches. The bedding-planes trend a little north of east, and dip south 62 degs., so that the vein forms an acute angle with them. 25 feet farther down, the vein consists of white quartz sharply curved in a double-cleaved or jointed rock (Fig. 21, Plate X.). The average dip is south 30 degs. In the lowest working (100 feet below the first) the dip is south 51 degs., and the thickness is 2 feet of white quartz strongly cleaved and jointed. Samples from the

surface-workings averaged 5 dwts. of gold to the ton. Old workings exist under this vein which were inaccessible at the time of the writer's visit.

A tunnel, 600 feet above the river Chiquilá, and a little west of these workings, has cut two veins. The first was cut 50 feet from the mouth, it trends north $22\frac{1}{2}$ degs. west, and dips west about 45 degs. For some distance the lode was auriferous, consisting of 21 inches of white and comparatively tender quartz sprinkled with iron pyrites. Southward the lode takes a sharp turn east, and here the lode is much flatter, consisting of whitish quartz sprinkled with a little iron pyrites. The rock is bluish clay-slate. The vein averages 5 to 6 dwts. of gold to the ton; northward it is soft and worthless. About 20 yards farther west another vein or branch runs north-east and south-west, and dips south 45 degs., consisting of one foot of white quartz of very favourable appearance sprinkled with iron pyrites. It averages 10 dwts. (extremes, 5 dwts. and $3\frac{1}{2}$ ounces) of gold to the ton. It must form a junction with the first vein to the south, and is said to have done so in one of the stopes above, where rich mineral was found.

Near the eastern boundary of the La Virginia claim, a quartzose vein, 16 inches thick, is seen crossing the Arroyo north 35 degs. west to south 35 degs. east in clay-slate country. The vein has been proved superficially along the slope of the hill for a length of 350 feet, corresponding to a vertical height of 125 feet. At the top working, the vein is seen to be a red and yellow-stained dyke of felsite with a little gossan and quartz 3 feet thick in hard clay-slate rock (Fig. 22, Plate X.). 30 feet below this, the vein courses north-west, and dips south $72\frac{1}{2}$ degs. in a similar hard country. The vein-formation is $3\frac{1}{2}$ feet thick, the auriferous quartz consisting of a single layer lying near the footwall (Fig. 23, Plate X.). Divisional planes are traceable here trending east and west, and dipping south 75 degs. 70 feet below the last working, the vein consists of only 2 inches of quartz spotted with iron pyrites. The beds of the country here run east 35 degs. south to west 35 degs. north, and dip to south 51 degs. An average sample of the whole vein gave only a few pennyweights of gold to the ton. The country here is clearly uncongenial, and the vein is pinched below.

At the California mine, an auriferous quartz-vein is traceable for about 350 feet on the slope of a hill, corresponding to a vertical height of 150 feet. The lode strikes east 20 degs. south to west 20 degs. north, and dips from north $68\frac{1}{2}$ degs. to south 58 degs. At the top working, the vein is 6 feet wide, consisting of $2\frac{1}{2}$ feet of hard quartzose gossan with

iron pyrites on the hanging side, the rest being gossany clay (Fig. 24, Plate X.). The pyritous quartz assayed 2 ounces 13 dwts. 8 grains of gold to the ton, while the gossany clay only yielded about $\frac{1}{2}$ ounce. In the croppings below the vein is very thin, consisting of quartz, gossan, and iron pyrites from 2 to 9 inches thick, the assays varying from $1\frac{1}{4}$ to 9 dwts. In one place the quartz is white and non-mineralized.

At El Dorado, about 125 feet above the stream, a vein crops out trending north $32\frac{1}{2}$ degs. west, and dipping south-west 63 degs. It consists of ribs of quartz separated by layers of rock, and with gossan on the footwall. Samples from here have yielded from 9 dwts. to upwards of 5 ounces of gold to the ton. About 200 feet above this, another vein crops out bearing east 11 degs. south to west 11 degs. north, and dipping south $42\frac{1}{2}$ degs., from 12 to 18 inches thick of solid quartz sprinkled with iron pyrites. Assays from here gave only from 4 to 8 dwts.

At Concepcion, a vein trending east $21\frac{1}{2}$ degs. south and dipping south 44 degs., is seen cropping out in a *quebrado*; it consists of 20 inches of hard quartz, with iron pyrites and galena. The hanging-wall appears to be hard granophyre, and the footwall hard hornblende-dolerite. A few feet above, the vein thins away to 9 inches, while about 18 feet higher up, it appears only as 2 inches of soft green clay charged with two iron pyrites.

The prevalent direction of the veins in this district appears to be a few degrees from east and west with a southerly dip. Several veins trend in a north-westerly direction, dipping south-west. A north-easterly direction appears to be exceptional, as does also a northerly dip (Fig. 25, Plate X.).

Leaving the segregated veins out of account, which usually follow the bedding-planes, no well-defined system of fissure-lodes has as yet been discovered in this district.

The veins run in various directions, and individually many of them are very variable in strike. The beds of the country appear to vary considerably in strike also. At the Chorro workings, some of the beds appear to run north 35 degs. east and to dip south 43 degs., while others trend mostly a few degs. north of east and dip south 62 degs.; at La Reyna, about 10 miles farther south, some beds are seen coursing and dipping the same as the latter, but in the same mine other beds strike east 35 degs. south and dip south 51 degs. At Silencio, on the opposite side of the river, some beds appear to run east 10 degs. south and to dip south 36 degs. to 53 degs.; while at Socorro some beds trend north-west and dip south-west. The rocks are frequently so altered as to have their bedding-planes

obliterated—the complication is increased when, as is often the case, the rocks exhibit divisional planes running in various directions.

The fissure veins are evidently of later date than the schistose and eruptive rocks, as they pass indiscriminately through both.

It is extremely probable that all the veins have been filled by lateral secretion, *i.e.*, the mineral contents, including the precious metals, have come in from the adjacent rocks. Certain bands of the metamorphic rocks as well as of the eruptive dykes are strongly charged with iron pyrites, and this mineral may be looked upon as the main source of the gold in the veins. At and near the surface, the well-known decompositions have taken place, resulting in the production of earthy brown oxide of iron (gossan) and the setting free of the gold.

The association of manganese with gold has frequently been noticed. In this district the gossany veins are often characterized by the presence of this ore, and, in certain instances, they are specially auriferous when crossing bands of oxide of iron, manganese, and clay.

It should be noted that in some countries—Venezuela for example—manganese is looked upon as a sign of poverty.*

In some gold veins the presence of galena is regarded as a favourable indication. This appears to be the case in this district, although the galena itself carries little gold.

Gossan containing visible gold is usually regarded as a favourable feature for the precious metal occurring in depth, but, speaking generally, this is certainly not the case in this district. The gossany veins die out rapidly in depth, while the quartz fissure-veins seldom carry gossan at the surface.

Some of the quartz fissure-veins appear to widen while others seem to pinch out in depth—but the latter may only be a temporary thinning due to hard and uncongenial rock.

Although the quartz fissure-veins sometimes follow the direction of the bedding-planes, they more frequently cut them at an acute angle, obliquely, or at right angles; they sometimes, too, follow the lines of contact between the sedimentary and eruptive rocks, and sometimes follow the dykes for a certain length, as well as the divisional planes.

Mr. John C. F. Randolph† says that no true fissure-veins have yet been discovered in Tolima, and they are all classed by him under the head of bedded-veins. His observations, however, do not appear to have been

* *Les Filons d'Or de la Guyane Française*, L. F. Viala, 1886, page 35.

† "Notes on the Republic of Colombia, S.A.," *Trans. Am. Inst. Min. Eng.*, vol. xviii., pages 205-213.

extended so far south as Organos. Even with regard to other districts this is a sweeping assertion to make, and the writer believes it is not borne out by facts.

Quartz appears to be the only true gangue in these veins, and the metalliferous species are extremely few in number, being confined almost entirely to auriferous iron pyrites, auriferous and argentiferous galena, blende, the oxides of iron and manganese (secondary), and a mineral not yet determined.

In the quartz fissure-veins the band of quartz, which is generally found on or near the hanging-wall, may be looked upon as the filling of the original fissure; other bands frequently occur adjacent to or near this, filling subsidiary fissures, or are the result of replacement of the country-rock.

The rock on either side of the original fissure is often decomposed and mineralized, and frequently exhibits joints or fissure-planes parallel thereto. These were probably produced contemporaneously, and those that limit the mineral contents may be regarded as the hanging and footwalls of the vein.

The country within the lodes may be looked upon as altered or unaltered rock *in situ*; and the original fissures were probably, in the first instance, mere cracks in the country rock.

In places there is evidence of strong local disturbance in the rocks, due probably to great lateral pressure, which has produced local movements of one bed over another, resulting sometimes even in fracture (Figs. 1 and 4, Plate IX.).

Finally, the behaviour of the quartz fissure-veins may generally be said to be irregular, and its peculiarities are as follows:—

1. The thickness varies considerably, and sometimes at short distances, both horizontally and vertically, from a mere joint-plane to about 6 feet, the latter being rarely exceeded. The average would appear to be about 2 feet.

2. The dip also varies considerably, although its general direction is nearly always south or south-west, according as the vein runs in an east and west or north-westerly and south-easterly direction respectively. The dip is rarely northerly or easterly, and when so the lode is usually marked by poverty.

3. The strike is still more variable, and although some of the veins appear to follow the law of average bearing,* others appear very capricious in this respect.

* Moissenet, *Parties riches des filons*.

Los District, U. S. Colombia."

FIG. 5.

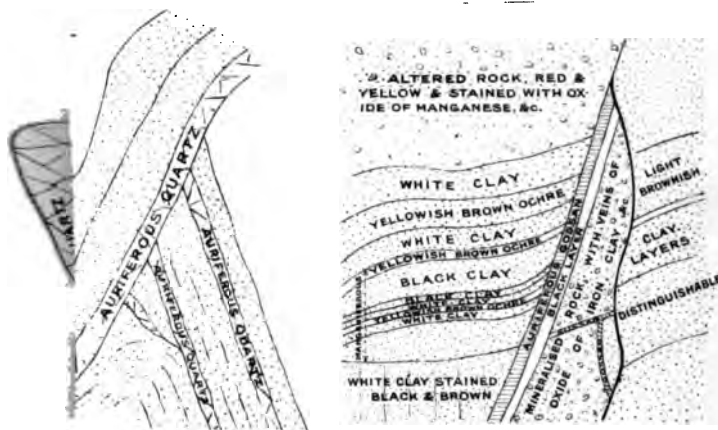


FIG. 9.

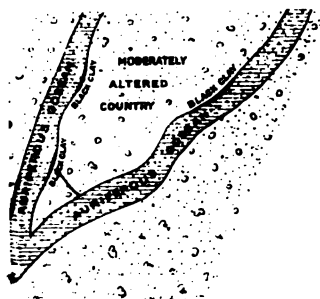


FIG. 10.

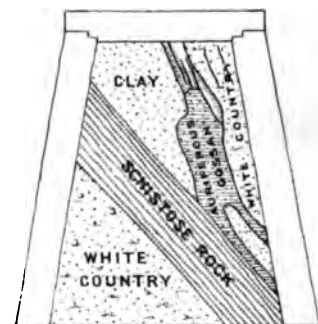


Fig. 14.



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FIG. 18.

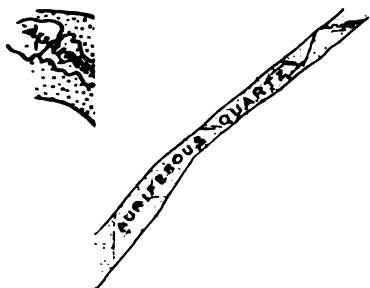


FIG. 19.

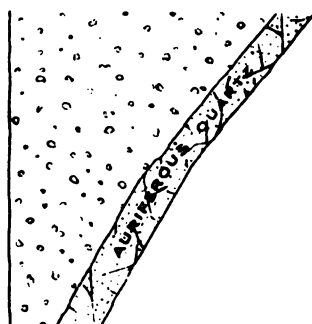
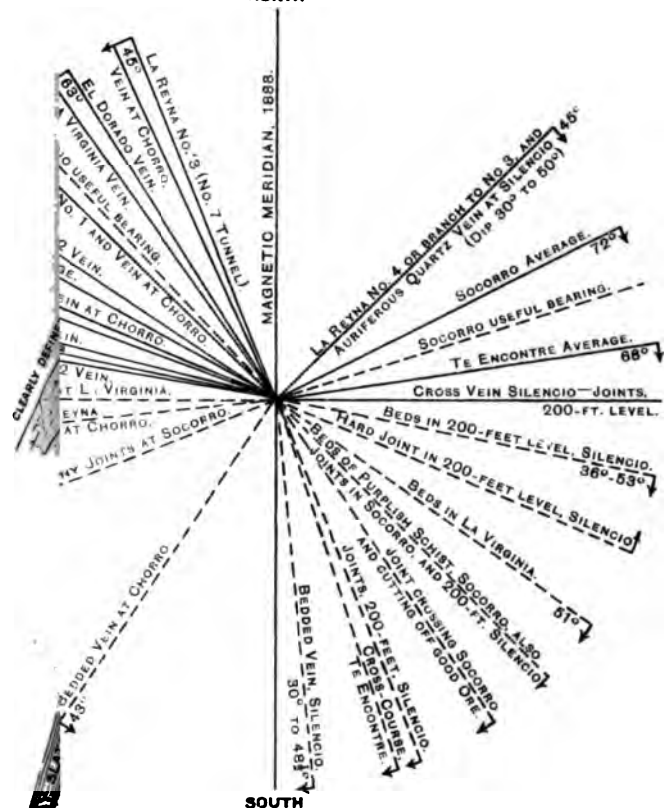


Fig. 25.
NORTH



REFERENCE.

Strike and Dip of Veins

*Strike and Dip of Joints, }
Beds or Bedded Veins }*

4. The walls are sometimes ill-defined, especially in the eruptive rocks. In Figs. 16 to 20 a fairly well-defined hanging-wall is observable, while the quartz leader, which we may regard as a footwall, is often flat and irregular.

AURIFEROUS IMPREGNATIONS.

In addition to the deposits described in the paper there is another class in the district which may be termed auriferous impregnations. They occur in highly kaolinized granophyre, and run as a rule very irregularly, and appear to possess no walls or joints.

At the Silencio mine, a deposit of this class has been opened near the surface. It seemed to run roughly north-east to south-west, and to dip flatly to the south-east. The rock appeared to have been subjected to the action of thermal waters from which hydrated oxide of iron and native gold had crystallized out. The mineral bore a great resemblance to specimens from the famous Mount Morgan mine of Queensland, but unfortunately it was not found in any quantity. Specimens occur rich in visible gold, but the average does not probably run more than half an ounce to the ton. It is believed that most of the gold occurs in the mineral in a very highly divided condition.

Veins crossing these gold-impregnated beds would probably be found to be highly enriched therein.

The gold in the Organos district contains a good proportion of silver, and is only about 650 fine.

The PRESIDENT asked whether the mines were worked to any great extent, what was the quantity of gold produced, the number of workmen, etc.?

Mr. E. HALSE replied that a large quantity of gold was not produced at present in the district described; the value might perhaps be put down roughly at from £10,000 to £15,000 sterling per annum. The mines were being extended, and new veins were being opened out, so that in future the district might become a much more important one than it was at present.

Mr. W. COCHRANE asked whether the district was likely to become competitive with other gold-bearing districts of other parts of the world?

Mr. HALSE said at present it could not be considered as an important district, but he could not say what it might become with further development.

CORRESPONDENCE.

Mr. DAVID BURNS wrote that the Organos mining-field seemed calculated to intensify the mystery that surrounded the origin of veins, rather than to afford material for a solution of the problem. The features recorded are pretty much what obtain when veins occur in extremely metamorphic rocks, save that the veins appeared to be of a specially weak and fragmentary character, but probably more extended operations and deeper working would show a greater continuity than now appears probable. It is abundantly clear from this paper and from many other observations, that the contents of the bedded veins were to a great extent determined by the surface of the ground, and that consequently they were filled when the surface-configuration was approximately what it is now. This is proved by the contents of the veins altering in depth, and in most cases disappearing altogether. The conversion of pyrites into gossan is easily explained by atmospheric influences, but the displacement of auriferous quartz by flucan, as greater depth is attained, admits of no such solution. Neither does the segregation idea help us at all. Let us suppose that a limited amount of intensely heated and highly fluid mineral substances was escaping from the interior along contact-planes as being the planes of least resistance. So long as these substances remained perfectly fluid, they would allow the rift between the rocks to close behind them, but when they began to cool down and became viscous, they would begin to clog up the vent, those with the lowest melting-point getting nearest the surface. This assumption explained why such veins so frequently disappear in depth and present a distinct succession of mineral in depth. It was inconceivable that pyrites and quartz could traverse the planes of bedding of the country-rock by any other agency than galvanic action. If galvanic action had caused the segregation, would not the metals of the veins be found in continuous ribs, and the metals in the metallic form instead of as ores? Metalliferous veins are generally found intersecting dykes and cross-courses and are thus proved to be of later age, and they may be of a much later period than has hitherto been suspected. Mr. Halse says "the rock on either side of the original fissure is often decomposed and mineralized, and frequently exhibits joints or fissure-planes parallel thereto," but this feature was well explained by the theory of the eruption of vein-stuff from below, and not at all by the author's theory of secretion. Much of the quartz and clay in the veins may be the country rock completely metamorphosed by the hot erupted vein-matter, whereas the rocks just referred to have been less altered. The fissure-veins that appeared to widen in depth are probably

stronger or have had more cover than those that narrow downwards ; and those that widen in depth will ultimately narrow if followed far enough ; their fluids having been able to expend most of their energies before reaching the surface, while those that are widest at the outcrop have not.

Mr. E. HALSE wrote that Mr. David Burns appeared to think that veins were filled by mineral substances ascending them in a more or less molten condition. This seems an extraordinary view to take, and one to which the writer believes the present structure of veins lends no support whatever. On the contrary, all the evidence seems to show that the mineral substances were deposited from chemical solution (presumably from heated waters, but not necessarily so in all cases). The writer has advanced no new theory in his paper, but he has taken the most generally accepted one, that of lateral secretion—first outlined by Delius in 1770, and in recent years propounded with much scientific evidence by Fridolin Sandberger,* and largely supported by such keen observers as Emmons, Curtis, Becker, and others—as explaining best the mode of filling of at least the superficial veins of the district described. No single theory will explain all the phenomena connected with mineral veins, nor can it be expected to do so, for the structure is often extremely complicated, owing probably to the veins having undergone many physical and chemical changes since the first filling.

The PRESIDENT proposed a vote of thanks to the writer of the paper.

Mr. M. WALTON BROWN seconded the vote of thanks, which was cordially adopted.

The Rev. G. M. CAPELL read the following paper on the “Manometric Efficiency of Fans” :—

* *Untersuchungen über Erzgänge*, 1882, 1885.

MANOMETRIC EFFICIENCY OF FANS.

BY THE REV. G. M. CAPELL.

It is now about ten years since the term "manometric efficiency" was brought prominently forward by Mr. Daniel Murgue, and the term is one not generally understood. It refers simply to the relation of the water-gauge to the speed of the blade-tips of a fan, and has no necessary relation to the useful effect of a fan.

Mr. G. Herbst, in speaking of fan tests, specially remarks that high manometric effect does not necessarily imply high useful effect. In fact the evidence of tests by Fan Commissions prove the exact contrary, as will be shown later on. When we consider that the water-gauge and volume represent two sides of a balance, of which the water-gauge represents the longer arm, it seems natural to expect, if the water-gauge be reduced, that the volume of air will be increased, and with it the useful effects at a given speed. With high manometric effect, the fan is not working on a full flow of air, and consequently is wasting power in creating the high vacuum implied in a maximum water-gauge with a minimum quantity of air passing.

In the trials of Guibal fans by the Committee of the North of England Institute of Mining and Mechanical Engineers,* the 50 feet Guibal fan at St. Hilda colliery showed a useful effect of 42·09 per cent., while the manometric effect was 64·1 per cent.; the 40 feet Guibal fan at Pemberton colliery showed a useful effect of 52·95 per cent., with a manometric effect of 52·1 per cent.; the Guibal fan at Cannock Wood colliery showed a useful effect of 47·95 per cent., with a manometric effect of 56 per cent.; and the Waddle fan at Celynyn colliery, with a useful effect of 50·5 per cent., gave a manometric effect of 45·7 per cent.

Another consideration comes in next, that is the position of the end of the water-gauge tube. In all the early Guibal fans the water-gauge tube was placed either in the centre of the inlet over the bearing or in the fan case. Now this makes a considerable difference in the calculation of the manometric effect. If another water-gauge were placed on the

* *Trans. N. E. Inst.*, vol. xxx., page 273.

drift, 20 feet from the fan inlet, another and a lower reading would be shown. There is an instructive example in the trials of the 30 feet Guibal fan at Staveley colliery by Mr. Robert Howe,* at 56 revolutions of the fan the water-gauge in the inlet was 2·52 inches, with a manometric effect of 73 per cent.; but the water-gauge in the drift was 2·10 inches, with a manometric effect of 60·3 per cent. There is a difference of about 13 per cent. in the manometric effect, obtained by changing the water-gauge from a position at the fan-inlet to the drift-door, which was close to the fan-inlet. At a distance of 20 feet, the manometric effect would have been much less.

In recent trials of fans by a private commission in Belgium, there is an interesting series of diagrams showing the position of fan-inlets and the water-gauges at various points. At the Rieu-du-Cœur colliery, a Rateau fan has been erected, and this fan is said to show a manometric effect of 80·2 per cent., with a useful effect of from 35 to 47 per cent. The position of the water-gauge tube was peculiar. The conical adjutage, joining the fan to the drift, is of small diameter, not above $4\frac{1}{2}$ feet, and the water-gauge tube is placed in it. With 59,488 cubic feet of air passing, the velocity would be 4,210 feet per minute in the tube, and, by Dr. Hutton's rule, the water-gauge due to that velocity would be 1·70 inches, representing a very large deduction from the 4·29 inches shown, had the gauge been taken on the door of the large drift, from which the fan was drawing. Yet a comparison is made of the manometric effect of that fan, with its water-gauge tube in the position described, with that of a Capell fan at the Prosper colliery, with the water-gauge tube placed about 90 feet from the double inlets of the fan, in a drift of 55 square feet area, the water-gauge showing 6·10 inches.

If manometric effects are to be of any use in comparisons, the conditions of taking them should be settled, as they become misleading when made under wholly different conditions. In the report of the Belgian Commission, only the Guibal fans appear to have been tested under similar manometric conditions.

Another point is worthy of notice, that a very small fan passing a large volume of air has to raise that air to a high velocity; and velocity means work done, and it is fair to measure the work done, remembering that the static water-gauge (*i.e.*, the water-gauge taken out of the air-current in the fan-drift) is the water-gauge which should be effective for the ventilation of a mine. That water-gauge can always be ascertained by taking a reading on the outer door of the fan-drift, the inner door being open. If

* *Trans. Chesterfield Inst.*, vol. i., page 46.

all water-gauges were taken thus, the useful effects would become less, as at present calculated, but the real effective work of fans would become clearer.

The writer has found that the highest useful effects in fans of the double centrifugal type is obtained between 47 per cent. and 54 per cent. of manometric effect. This agrees with the results of the Committee of the North of England Institute on Guibal fans, and brings the useful effects of Guibal fans down to the level of fans placed on Belgian mines by Mr. Guibal. The position of the water-gauge tube in fan tests determines not only the manometric efficiency, but the mechanical efficiency; and the reduction of the mechanical efficiency becomes a serious matter in a case where, with one fan, the water-gauge tube is placed, say, 60 feet away from the inlet of the fan, while with the other fan the water-gauge tube is placed in or close to the inlet. It follows, that in such calculations, some fixed distance from the inlet should be settled for the water-gauge tube end, so as to avoid conclusions which are misleading and inaccurate.

Another point of discussion is whether the water-gauge effect on the mine ventilation is the same with a double-acting as with a single-acting centrifugal fan. Experiments with two fans acting in succession, *i.e.*, one fan discharging into the inlet of another, show that the effect is not the same as with only one fan acting on the mine at a given speed. The writer believes fully in the difference, and this is a point which would at once raise a question as to the real worth of exceptionally high manometric effects.

The manometric rule of Mr. Murgue shows a theoretical gauge double of that given by Mr. Guibal $h = u^2 \div g$; while Mr. Guibal used $h = u^2 \div 2g$.

A curious point comes out in examining these water-gauges and manometric effects. If a fan gives 80 per cent. of manometric effect, then the speed of the air flowing into the vacuum, formed by the revolving blade-tips, is greater than the velocity of the actual circumference of the fan. Take the case of a fan 9.2 feet in diameter, giving 80 per cent. of manometric effect at 228 revolutions and 4.29 inches of water-gauge. The velocity due to a depression of 4.29 inches, calculated by the following formula: $v = \sqrt{h} \times 66.1$, is 136.7 feet per second or 8,202 feet per minute, while the periphery speed of the fan is only 6,578 feet per minute. It is extremely probable, if a lower velocity of blade-tip speed can raise a depression producing a higher speed of air, that there are some deeper problems underlying the action of centrifugal fans than have been thought of, and the whole theory of fan action may have to be revised.

The object of the writer of this paper is to show that high manometric effect does not necessarily imply high useful effect, and also to point out the need of some accepted rules for testing fans, to avoid unsafe results in manometric effect and useful effect in comparing fans, where the water-gauge has been placed under entirely different conditions.

Further trials were made on May 23rd last, of the Guibal and Capell fans at the Marles collieries, in the north of France. The results were:—

	Guibal Fan.	Capell Fan.
Fan, diameter (feet)	23	12½
Revolutions per minute, engine ...	75	63
Do. do., fan	75	306
Water-gauge, near inlet (inches) ...	1·40	9·10
Do. in main drift in a recess, and common to both fans (inches) ...	0·95	8·35
Volume of air per minute (cubic feet)	72,559	203,328

The difference of 0·45 inch between the inlet and static water-gauge in the case of the Guibal fan is very large, while the difference between the inlet and static water-gauge in the case of the Capell fan is only 0·75 inch. The efficiency of the Guibal fan is very low, being only 39 per cent. of the inlet water-gauge.

The PRESIDENT said he thought it would be desirable in discussing this paper, to take at the same time the discussion on the following papers:—"Observations on Fans of Different Types Working on the same Upcast Shaft," by the Rev. G. M. Capell;* and "Experiments upon a Waddle Fan and a Capell Fan Working on the same Mine at Equal Periphery Speeds at Teversal Colliery," by Mr. J. C. B. Hendy.†

Mr. W. COCHRANE said he would like Mr. Capell to make his meaning perfectly clear as regards the manometric efficiency. In the paper it was said to refer "simply to the relation of the water-gauge to the speed of the blade-tips of the fan, and had no necessary relation to the useful effect of the fan." Did this mean that the manometric efficiency was the water-gauge (irrespective of where it was taken) compared with the theoretical water-gauge? If so, it was simply the relation of the indicated water-gauge (the water-gauge itself, measured and seen) to the theoretical water-gauge; and he wanted to know whether the latter was based upon $h = u^2 \div g$ or $h = u^2 \div 2g$?

Mr. A. L. STEAVENSON referred to the same paragraph as to the manometric efficiency in which Mr. Capell said "it refers simply to the

* *Trans. Fed. Inst.*, vol. iv., page 203.

† *Ibid.*, page 474.

relation of the water-gauge to the speed of the blade-tips of a fan, and has no necessary relation to the useful effect of a fan." If they took any ventilator and found that some part of its work was performed more efficiently than in any other fan, it followed that the useful effect, all things being equal, would also be higher. Mr. Thomas Bell (H.M. Inspector of Mines) and Mr. Cooke were the first to make observations upon the pseudo water-gauge, and they noted that the water-gauge in the case of the Guibal fan had in all cases exceeded $u^2 \div 2g$, which, he thought, was accounted for by the action of the évasée chimney. Undoubtedly the évasée chimney entirely altered the conditions under which the speed of the blade-tips governed the theoretical water-gauge. The general law of the manometric efficiency of fans was now so well established that it could not be resisted; in fact, Mr. Capell had recognized the advantage of the évasée chimney, and now used it in the construction of his fan. The only question now in dispute was the position of the water-gauge. He thought the proper position was at such a distance from the fan that it was not affected by the speed of the fan, say, for instance, at the bottom of the pit.

Prof. J. H. MERIVALE said he understood Mr. Capell to say that it should be taken as near to the fan as possible, and where the air was practically at rest. The best position would be in the fan-chamber.

Mr. CAPELL said with regard to the question of the higher manometric efficiency necessarily implying a higher useful effect, his own experience was diametrically opposed to such a conclusion, and in the recent experiments at Marles colliery, carefully conducted by capable engineers, they arrived at a result which was a startling surprise.

Mr. W. COCHRANE asked the meaning of "double centrifugal type of mine-ventilator," and whether it applied to others than the Capell fan? Would he call the Guibal or Waddle fans "double centrifugal"?

Mr. CAPELL said they were single-centrifugal fans, but the Pelzer and Rateau fans were of the double centrifugal type.

Mr. W. COCHRANE referred to Mr. Capell's statement that "some fixed distance from the inlet should be settled for the water-gauge tube-end, so as to avoid conclusions which are misleading and inaccurate." If he (Mr. Cochrane) remembered rightly, Mr. Capell argued in a previous discussion* that the principle of the Capell and similar fans was such that they carried back (for the same velocity of blade-tip) a water-gauge very much farther into the mine than any other kind of fan; therefore, if at the surface, a distance of 20 feet or so away, were settled as a

* *Trans. Fed. Inst.*, vol. iv., page 204.

suitable position for the water-gauge, an advantage would be claimed in all cases for Capell fans and those of similar type; that is, that they would be able to indicate a higher water-gauge at a distance of 20 feet from the fan than any other fan. The Guibal fan at Marles, which produced 72,559 cubic feet at 0.95 inch water-gauge, in the fan drift would produce 203,000 cubic feet in the same mine at 7.436 inches of water-gauge. It seemed to him that the Capell fan indicated a higher water-gauge to circulate this volume than the Guibal fan, but such higher water-gauge was not required, and ought to yield, if utilized, a much larger volume of air than 203,000 cubic feet per minute.

Mr. CAPELL asked what would have been the water-gauge of the Guibal fan when circulating 203,000 cubic feet per minute?

Mr. COCHRANE—In the proportion of $72^2 : 203^2 = 0.95 : 7.436$ inches.

Mr. A. I. STEAVENSON said that if they took the experiment on the Guibal fan and used the formula $u^2 \div 2g$, they got an efficiency exceeding 100 per cent., which was impossible. It was necessary to recognize the effect of the *évasée* chimney, and the square of the speed of the periphery should be divided by g and not $2g$.

Mr. T. H. M. STRATTON said he would leave the scientific part of the discussion to Mr. Cochrane, but he thought Mr. Capell was under a mistake if he assumed that the manometric efficiency had anything to do with the useful effect. If they had a fan perfectly suitable to the size of the mine, running at a certain speed, and with its outlets and intakes adapted to that mine, they obtained a high useful effect, but they could not predict the proper size of fan to put up unless they knew the area of the orifice of the mine.

Mr. W. C. BLACKETT said he was in considerable doubt as to what Mr. Capell meant to convey by his paper, more especially as to water-gauges. From his use of the term "static" as applied to a water-gauge in one part of his remarks, and in another to some mysterious influence "thrown back from the fan," he (Mr. Blackett) was not able to say whether the difference was due to this mysterious influence "thrown back," or to the dynamical effects of the air-currents. As Mr. Capell used the word "static" he thought he had in mind the dynamic effects of air-currents passing the open mouth of a tube connected with the water-gauge; this was one thing, but this influence "thrown back" from the fan was another, and he (Mr. Blackett) could not quite understand whether in speaking of having to be careful against the static gauge they were to be careful to get out of this mysterious influence or to get

out of the influence of the dynamic effects of air-currents. In the latter case, he did not see how putting the water-gauge on the second of the separation-doors got over the difficulty, as in that case they simply altered the shape and length of what might be called equivalent to the tube of the water-gauge. He understood Prof. Merivale to say that it was not necessary for the air in connexion with the water-gauge to be perfectly at rest, but Mr. Capell considered that it should be at rest. But he (Mr. Blackett) took it that in all water-gauges connected by the fan-drift with the tube, the air in the tube was at rest, and merely altering the shape of the end of the tube and expanding it into a passage at right angles—or any other angle—to the fan-drift did not provide them with air not in motion, and he thought in fact the widening out of the tube and placing the widened mouth against the air-current might prevent them getting much water-gauge at all. About fifteen years ago he made some experiments upon a Schiele fan with the special object of getting to know the influence of the position and direction of the pipe upon the readings of the water-gauge, in relation to the air-current and the orifice of the fan, and he was able to get from 0·30 inch with the pipe-mouth facing the current to over 2 inches where the pipe was reversed, and there was at the same time about 0·50 inch registered on the drift doors. Although Mr. Cochrane might be in doubt as to which theoretical water-gauge ought to be accepted, there was considerably more doubt as to how they were to measure the practical water-gauge, and he had not heard anyone yet give any rule as to taking a water-gauge that would be equally applicable to any fan-drift. He thought they would always have differences in their observations—one gentleman on one side doubting the veracity of another gentleman on the other side as to the results produced from their respective fans—unless they could hit upon some contrivance, be it simple or otherwise, for getting a water-gauge free from all influence of air in motion, and especially free from that mysterious influence which Mr. Capell said was capable of being “thrown back” from the fan.

Mr. A. L. STEAVENSON said he thought he could elucidate the matter. The water-gauge decreased as they got farther away from the fan, until they reached a point at which it became practically constant. If a fan created a vacuum giving more air than the fan could contain, they would get a pseudo water-gauge. A large fan of 40 or 50 feet in diameter produced no pseudo water-gauge; but a small fan running on a large mine produced great pseudo water-gauge, because the vacuum produced more air out of the mine than the fan could swallow.

Mr. W. C. BLACKETT rejoined that Mr. Steavenson's statement proved that he was more influenced by the mysterious influence of the fan "throwing back" than by the dynamical effects of the air-current, and he (Mr. Blackett) was still in as much doubt as ever as to which should have the more importance attached to it.

Mr. CAPELL said that in order to avoid all dynamic influence of the current on the water-gauge, he had tried the experiment of using a sharp pointed tube, which he drove into a ball of worsted where nothing could get at it. For practical use a tube of perforated zinc placed on the end of the water-gauge tube, and covered with cotton-wool and then wrapped over with several layers of flannel was equally efficient.

Mr. T. H. M. STRATTON said that roughly speaking, they might put the manometric efficiency of the Guibal fan at 0.64 and the Waddle, Schiele, and Capell at 0.46.

Mr. FERRIER said he did not think the manometric efficiency affected the mechanical efficiency, for the highest manometric efficiency was obtained when the mine was shut off, when the mechanical efficiency was *nil*. He did not see how the dynamic effects could very readily be produced in a substance of such small density as air; in hydraulic experiments they had a very great effect on the pressure at a particular point along the pipe through which the water was passing, but he thought this was very different to what the effect would be on a substance of such small density as air. The energy must be very small in consequence of the small weight of air, and it was difficult to see how the dynamic effect could produce an appreciable effect on the water-gauge. They might suppose that the pressure would form rapidly as it went along the drift to the end of the fan, but it would be difficult to find at what part it would be best to place the water-gauge; it would depend largely on the passage through which the air was moving; the larger the area through which the air was passing the less the pressure required to drive it through.

Mr. CAPELL said if they took a glass tube 3 feet long and blew across its end they would get a water-gauge of 14 or 15 inches, and this was exactly what happened in a tube placed in a very high velocity of air-current; the air whistling past its end raised the observed water-gauge to a higher point than the static water-gauge would be.

Mr. J. C. B. HENDY said that he agreed with Mr. Capell's remarks as to the dynamic results observed in the drift. The dynamic water-gauge would be due to the velocity or impulse of the air passing the orifice of the tube; that is to say, if the orifice of the water-gauge tube was uncovered in one instance and covered in another, there would probably be a

difference in the water-gauge, and that difference would be due to the dynamic effect. He understood Mr. Capell to say, in the paper he had just read, that a fan might have a very high manometric efficiency and at the same time a low mechanical efficiency, and that one machine might be a better ventilator with a high manometric efficiency and a low mechanical efficiency, than another machine which gave a comparatively low manometric efficiency and high mechanical efficiency. This raised the question as to whether they were to judge the fan and engine as a whole, or one machine, or to separate the two and simply judge the fan from its manometric efficiency and the volume of air it produced. No doubt the fan might suffer in the comparison if driven by a badly constructed or inefficient engine, but on the other hand they ought to know which fan required the most engine power, and he thought that experiments ought to be made so as to obtain such data as would enable them to make a fair all-round comparison. In most of the cases quoted by Mr. Capell where a Guibal or other large fan had been replaced by a Capell fan, it should not be forgotten that the former had been replaced by a Capell fan designed to give a much larger volume of air than the old fan was capable of exhausting, and (in the comparisons he makes) he gives the calculated water-gauge required for the old fan against the actual water-gauge obtained with the new fan. He did not think it was right to compare the calculated water-gauge from a fan designed to produce say 50,000 cubic feet per minute with the actual water-gauge given by a new fan designed to produce 120,000 or 150,000 cubic feet per minute. What they wanted was a comparison between fans each designed for the same duty and working under the same conditions, and so far as he could remember Mr. Capell had not quoted any such instance.

Mr. M. WALTON BROWN said that Mr. Guibal (many years ago) showed that in either a cased or open-running fan a force equal to that induced by the velocity of the circumference was wasted, and he further proved that the ideal centrifugal fan should be provided with an expanding-chimney or similar apparatus which would utilize the work remaining in the air on its issue from the fan. If that adjunct was of infinite dimensions, Mr. Guibal showed that the water-gauge would be doubled, and it had not been found difficult in practice to make a centrifugal fan, provided with an expanding-chimney, produce 80 to 83 per cent. of the theoretical yield calculated by the formula $u^2 \div g$. In other words, Mr. Guibal accepted $u^2 \div 2g$ as the value of the theoretical water-gauge produced by either cased or open-running centrifugal fans; and in the case of the ideal centrifugal fan provided with sliding-shutter and expanding-chimney, he proved that this value of the theoretical water-gauge was

doubled, or $2(u^2 \div 2g) = u^2 \div g$, which agrees with Mr. Murgue's formula. He (Mr. Brown) could not accept Mr. Capell's view that the manometric efficiency of any type of fan could be considered as having a constant fixed value, irrespective of the conditions of the mine. The following table records the work of the old single open-running inlet fan at Birch Coppice colliery,* together with certain calculated results deduced

No. of Experiment.	Observations.			Calculated Results at 106·1 Revolutions per Minute.			Squares of Volume. (v^2 .)	Water-gauge.		Ratio of Observed (h) to Theoretical Water-gauge ($h' = 1\cdot988$ in.).
	Revolutions per Minute.	Volume of Air per Minute.	Water-gauge.	Equivalent Orifice.	Volume of Air per Minute. (v .)	Water-gauge. (h .)		Calculated. (h' .)	Difference. ($h - h'$.)	
		Cubic Ft.	Ins.	Sq. Ft.	Cubic Ft.	Inches.		Ins.		
1	152	70,280	1·10	24·75	49,057	0·536	2,406,599,249	0·577	-0·041	0·269
2	120	60,000	0·70	26·53	53,050	0·547	2,814,302,500	0·544	0·003	0·275
3	137	73,000	0·90	28·47	56,535	0·539	3,198,206,225	0·513	0·026	0·271
4	137	73,000	0·85	29·30	56,535	0·509	3,198,206,225	0·513	-0·004	0·256
5	152	118,498	0·45	65·35	82,714	0·219	6,841,605,796	0·216	0·003	0·110

therefrom. If a diagram be made with the squares of the volumes (v^2) as abscissæ, and the observed water-gauges (h) as ordinates, a straight line could be drawn approximately through the five points, having for its equation $h = 0·773$ inch - $0·000,000,000,081,5 v^2$. The calculated water-gauges (h') are obtained from this formula, and the difference ($h - h'$) shows the apparent errors. These differences are slight, except in the case of No. 1 experiment, and may be set down to errors of observation. Taking the initial water-gauge (0·773 inch) and the observed water-gauge (h), it will be seen that the manometric efficiency is not constant for the Birch Coppice fan, and that it varies from 0·462 at the initial water-gauge, to 0·110 in No. 5 experiment. Mr. Capell, in a previous paper,† alleges that there is "a different water-gauge in the Guibal fan when passing the same volume of air as the small Capell fan," and "the lower gauge for a given work in air shows itself wherever the Capell fan has replaced a Guibal fan." The statement is not borne out by the experiments recorded in Mr. Capell's paper, as the comparison is made by calculation of the results of the Guibal fan at a low peripheral speed with those of the Capell fan at a much higher peripheral speed, and not by direct comparisons of the water-gauges of both fans when actually passing the same large volume of air. Thus at Prosper I collieries, the Guibal fan producing a volume of 59,340 cubic feet is compared by calculation with

* *Trans. South Staffs. Inst. Min. Eng.*, vol. xi., page 74.

† *Trans. Fed. Inst.*, vol. iv., page 203.

the Capell fan volume of 127,574 cubic feet per minute; and at Marles, the Guibal fan exhausting 72,559 cubic feet is compared with a Capell fan producing 203,328 cubic feet per minute. The manifest unfairness of such comparison of the results obtained by one fan with those produced by another fan running at a much higher peripheral speed is clearly evidenced by a comparison of Nos. 1 and 5 experiments upon the Capell (12½ feet double-inlet) fan at Silverhill colliery,* as follows:—

	No. 1 Experiment.	No. 5 Experiment.
Revolutions of fan per minute ...	123	215
Volume of air per minute (cubic feet) ...	110,920	199,550
Water-gauge in fan-drift (inches) ...	1·40	4·10

Taking No. 1 experiment of 110,920 cubic feet under 1·40 inches of water-gauge, the Capell fan would require not less than 4·50 inches of water-gauge instead of 4·10 inches, actually observed in No. 5 experiment. These experiments show that a fan (in certain cases) yields better results than a fan running at a lower speed, and that such an unfavourable comparison at a low speed occurs equally in the case of the Capell fan as in any other fan. He (Mr. Brown) had considered the experiments made upon the Capell and Waddle fans at Teveral collieries, and he thought that the following experiments were worthy of comparison:—

Description of Fan.	No. of Experiment.	Diameter.	No. of Revolutions per Minute.	Volume of Air per Minute.	Water-gauge.	Reference.
		Feet.		Cubic Ft.	Inches.	
Capell ...	A ₁	16	113	88,045	1·40	<i>Trans. Fed. Inst.</i> — vol. iv., page 476.
Waddle ...	A ₂	30	52	87,729	1·00	vol. iv., „ 477.
Capell ...	B ₁	16	131	101,747	1·90	vol. iv., „ 476.
Waddle ...	B ₂	30	65	103,381	1·95	vol. ii., „ 543.
Capell ...	C ₁	16	135	116,494	2·20	vol. iv., „ 477.
Waddle ...	C ₂	30	70	114,309	2·15	vol. ii., „ 543.

The volumes in the above table, when reduced to a peripheral speed of fan of 6,000 cubic feet per minute, show the following comparative results:—

No. of Experiment.	Capell Fan.	Waddle Fan.
	Cubic Feet.	Cubic Feet.
A	93,000	107,400
B	92,700	101,200
C	103,000	103,900
Mean ...	96,200	104,200

* *Trans. Fed. Inst.*, vol. ii., page 549.

These experiments also prove that the Waddle fan produced practically the same volume of air at a much less water-gauge than the Capell fan at Teversal collieries.

Mr. CAPELL said that in considering the output of fans, the cubic contents of the fan and the output per revolution should not be forgotten. The Capell fan at Marles collieries had more than double the output per revolution of the Guibal fan. Working under the very high water-gauge required at Marles collieries, he calculated that 208,000 cubic feet would be exhausted at 310 revolutions per minute under 9 inches of water-gauge, and, as a matter of fact, at 306 revolutions the quantity of air was 203,328 cubic feet per minute under 9·10 inches of water-gauge, which was very near to the difficult guarantee which he had given. The rule for calculating the theoretical water-gauge referred to in his paper was Mr. Murgue's rule, $h = u^2 \div g$. On the Continent, this rule is now universally acknowledged, and the manometric efficiency is measured by its results. He (Mr. Capell) did not advocate taking the water-gauge close to the fan, as it was then influenced by local effects. Where practicable, it should be taken at a distance of 20 feet, and in a recess. He was questioned with regard to higher manometric efficiency implying higher useful effect; in the December (1892) tests of the Marles fan,* the manometric effect with a less volume of air than was obtained in May last was 0·547, with a mechanical efficiency of 0·578. A new form of shutter had been placed in the fan, and the chimney water-gauge had been decreased by its use. The result showed a corresponding decrease in the manometric effect, as in the last trials it was only 0·5109, but the useful effect rose to 0·591. The rise being about the same as the decrease in the manometric efficiency. The 12 feet single inlet fan, to which Mr. Brown refers, was the second Capell fan used on a colliery, and was an open fan of a type now discarded, and its results were not constant. The fan was an experimental one, from which useful deductions for future work were obtained. He (Mr. Capell) strongly protested against there being any unfairness towards a fan of 40 feet diameter and 10 feet wide at Prosper colliery being compared with a fan 12 feet 6 inches in diameter and 6 feet wide, or a fan 23 feet in diameter at Marles colliery being compared with another 12 feet 6 inches in diameter. The comparison is fair, as the large fans working on low water-gauges get the advantage of natural ventilation, which passes away when producing water-gauges of 6 inches to 11 inches. The unfairness, if any, seemed to be all the other way. Two independent observers have made tests of the Teversal fans, Mr.

* *Trans. Fed. Inst.*, vol. iv., page 215.

W. Piggford and Mr. Maurice Deacon. They have both proved the abnormal resistance required to get the air to the Capell fan inlet. Both of them have found that at the same water-gauge taken on the same water-gauge pipe for both fans on the drift, and in spite of the resistance between drift and inlet, the Capell fan has the advantage both in volume and useful effect. The water-gauge to get the air to the inlet from the drift is work done needlessly, and with a better arrangement the Capell fan would use that water-gauge in getting large volumes of air. As so much discussion had been raised over the trials of the fans at Teversal collieries, he hoped it might be possible to test the fans under nearly the same conditions by placing a temporary arrangement in the drift (if permission could kindly be given); but it would be quite impossible to get exactly the same conditions owing to the peculiar position of the Capell fan which is laid across the drift. Mr. Cochrane in his calculation had taken the static water-gauge as the water-gauge of the Guibal fan, instead of the inlet water-gauge, and had left out the effects of an important factor, the natural ventilation of the mine, which would come into action very strongly at the low water-gauge of 1·40 inches, in reducing the proportion between the inlet water-gauge and static water-gauge, but would not influence the high water-gauges. As a matter of fact there was a natural ventilation of about 16,000 cubic feet per minute at Marles colliery, and those who have studied the recent paper of Mr. T. A. Southern* will at once recognize how unsafe it is merely to rely on the squaring of the air-volume to get the water-gauge required for a large increase of the ventilation, unless natural ventilation is allowed for and a corresponding proportion of water-gauge added to the direct calculation from the squares of the volumes. In the Marles experiments, the 23 feet Guibal fan gave a useful effect of 39 per cent. on the water-gauge measured in the inlet of the fan, and 27·9 per cent. on the static water-gauge taken in a deep recess in the wall of the main-drift, which was 140 square feet in area. Hence, naturally, the static water-gauge useful mechanical effect of the fan had not been noticed in previous trials of this Guibal fan. The Guibal fan produced in round figures 72,000 cubic feet per minute at a water-gauge of 1·40 inches in the inlet to the fan; the static water-gauge for 203,000 cubic feet by calculation is obtained thus: As $72,000^2 : 203,000^2 = 1·40 : 11·109$ inches. The horse-power in the air is found to be: $203,000 \times 1·40 \times 5·20 \div 33,000 = 355·5$ horse-power; and at 39 per cent of useful effect, the Guibal fan would have required $355·5 \times 100 \div 39 = 911$ horse-power to have produced 203,000

* *Trans. Fed. Inst.*, vol. iv., page 460.

cubic feet of air per minute. The Capell fan results previously recorded show 291·5 horse-power in the air by water-gauge near inlet, and of 267·5 in the air by the static water-gauge; the engine being indicated at 495·0 horse-power; the useful effects being 59·1 per cent. by the water-gauge taken near inlet, and 54 per cent. by the static water-gauge. The contrast thus worked out is very clear, and the efficiency of the Guibal fan, worked out both on the inlet water-gauge and the static water-gauge, is also evident. The manometric efficiency of the Guibal fan at 75 revolutions, taking the inlet water-gauge, is 38·5 per cent., and taking the static water-gauge it is 26·12 per cent. The Capell fan, at 306 revolutions, gives on the water-gauge near the inlet 51·09 per cent. of manometric efficiency, and on the static water-gauge gives 46·8 per cent. of manometric efficiency.

The PRESIDENT said the discussion would now be adjourned, but in the meantime he thought their hearty thanks were due to Mr. Capell for endeavouring to enlighten them on these difficult problems.

The proposal was cordially adopted.

Mr. CAPELL responded to the vote of thanks.

DISCUSSION UPON PROF. F. CLOWES' PAPER ON "A PORTABLE SAFETY-LAMP, WITH ORDINARY OIL ILLUMINATING FLAME, AND STANDARD HYDROGEN-FLAME, FOR ACCURATE AND DELICATE GAS-TESTING."*

In the absence of Prof. Clowes, Mr. PALMER exhibited and explained the use of the hydrogen-oil safety-lamp.

The PRESIDENT asked if the lamp was in actual use?

Mr. PALMER replied that it had been in actual use for some months at the West Riding collieries.

Mr. A. L. STEAVENSON suggested that if the appliance would give equal results in ordinary coal-gas they might see some experiments with it now.

Mr. PALMER said this was not practicable, owing to the absence of a test-chamber.

Mr. M. WALTON BROWN emphasized the remarks he made when the lamp was shown at Derby,† and said that he would like information on

* *Trans. Fed. Inst.*, vol. iv., page 441. † *Ibid.*, page 456.

the following points :—(a) Was there any danger, when filling the hand cylinder with hydrogen from the large cylinder, of an explosive mixture being formed? If the valve of the hand cylinder was left open it might be filled with air, which would become explosive if mixed with hydrogen from the large cylinder, after the pressure had been reduced by repeated chargings of the hand cylinder. (b) The risk of the hydrogen being turned into the lamp at full pressure, and burning a hole in the gauze or cracking the glass. (c) The risk of the passage of flame through the pipe used for the introduction of the hydrogen gas from the hand cylinder. Prof. Clowes stated that* “It should be noted that the hydrogen-flame can be set to its standard height in the presence of the gas in measuring the flame-caps, and that the test can therefore be at once made in the air to be examined without previously placing the lamp in gas-free air.” He thought that if, say, 1 per cent. of gas was mixed with the air, the bulk of the hydrogen-flame would be enlarged accordingly, and it seemed to him impossible to adjust the hydrogen-flame to its standard height in such a mixture of gas and air. He thought the use of the lamp might be greatly simplified, if the gas could be produced chemically by an attachment to the lamp. He had used the hydrogen produced in a Döbereiner lamp as a test-flame for fire-damp, and suggested that Prof. Clowes might with advantage adopt a similar system.

Mr. PALMER, referring to the question of air being left in the cylinder, said that no harm would result, and two or three chargings would entirely remove it. He thought the lamp would be safe if the hydrogen were suddenly turned on at full pressure; the flame would simply shoot to the top of the lamp, but he did not think it would burn a hole through the gauze before being reduced.

Prof. MERIVALE observed that this point could be easily settled by experiments.

Mr. PALMER, continuing, said the hydrogen-flame was always of the same height, and there was a clear line of demarcation between the hydrogen-flame and the gas-cap, which were perfectly distinct.

CORRESPONDENCE.

Dr. P. P. BEDSON wrote regretting his absence during the discussion on the hydrogen-flame lamp, for he would have wished to express his admiration of the ingenuity displayed in the construction of the lamp. At the same time, he (Dr. Bedson) must confess to a feeling of disappoint-

* *Trans. Fed. Inst.*, vol. iv., page 451.

ment at the indications yielded in low percentage mixtures of fire-damp and air; in fact, in those ranges where an indication is most needed. The difference in the length of flame in $\frac{1}{4}$ per cent. mixture and $\frac{1}{2}$ per cent. mixture is practically useless as a means of gauging the amount of gas present, and does not compare at all favourably with the results of experiments with the Pieler lamp, made by the Austrian Fire-damp Commission, or of those conducted by Dr. Brookmann for the Prussian Fire-damp Commission. Dr. Brookmann states the difference in height of flame to be 2 centimetres (0.79 inch), which is about twenty times the difference in height of the hydrogen-flame. The Austrian Commission found a similar difference in the height of the flame, when experimenting with mixtures of Rossitzer gas, Segen Gottis mine, corresponding to $\frac{1}{4}$ and $\frac{1}{2}$ per cent. of marsh gas; whilst with other natural gases—the same difference in amount of marsh gas—the flames differed in height by 1 centimetre (0.39 inch), which is still ten times greater than the difference observed with the hydrogen-flame. These facts show the hydrogen-lamp cannot for such low percentages compare for delicacy with the Pieler lamp as an indicator of fire-damp. He (Dr. Bedson) would like to have asked Prof. Clowes how, when the lamp has once given an indication of gas, it is possible to set it without again bringing the lamp into an atmosphere free from gas. He (Dr. Bedson) understood that one of the disadvantages under which the Pieler lamp labours arises from the volatility of the alcohol; but the construction of the hydrogen-lamp requires the presence of a volatile oil, which is a factor of danger, just as alcohol is with the Pieler lamp. It would appear desirable that experiments with all such lamps should be made not only with marsh gas, prepared in the laboratory, but with gas collected in the mine, for, as shown in the experiments of the Austrian Commission, considerable differences may be observed, and it would be useful to know how these fire-damp indicators behave in different samples of fire-damp.

Dr. Clowes wrote that he fully endorsed the replies given by Mr. Palmer. In practice the small cylinder was found to be freed sufficiently from air by charging it once with hydrogen, and allowing this to blow off. Those who had used the lamp for some time underground, made no complaint of any difficulty in regulating the supply of hydrogen so as to avoid the production of an unduly large flame. The passage of flame outwards from the interior of the lamp through the hydrogen tube had been proved by many experiments to be impossible. Great importance is attached to the fact that in measuring the cap-heights, the hydrogen flame was always set to its standard height in air containing the known

percentage of gas. It is therefore unnecessary to remove the lamp to air free from gas in order to adjust the standard hydrogen-flame. Unfortunately the chemical generation of hydrogen gas from materials within the lamp had been long ago proved to be an impossibility. The flame of the gas chemically produced could not be regulated, and the metallic parts of the lamp were constantly corroded by the chemicals used. An experimental lamp, with which the attempt was made, never left the chemical laboratory. On the other hand, the present lamp, in which the hydrogen was prepared, and then applied in a compressed state, had, after lengthy trial worked very satisfactorily. He (Dr. Clowes) regretted that Dr. Bedson had not had an opportunity of seeing the hydrogen-oil lamp exposed to low percentages of gas in the test-chamber and in the pit. If this opportunity had been afforded (and Dr. Clowes was now prepared to offer it in any convenient way or time), no doubt would have been expressed as to the indications furnished by the lamp in $\frac{1}{2}$ and even in $\frac{1}{4}$ per cent. of gas. It would be seen that the cap-heights for these low percentages of gas ($\frac{1}{2}$ and $\frac{1}{4}$) were practically equal, but that the caps were distinguishable even by a novice without the slightest hesitation. The $\frac{1}{4}$ per cent. cap is hazy, pale, and indefinite in outline, but perfectly visible, and the $\frac{1}{2}$ per cent. cap is much less pale, and is comparatively well-defined. The caps are not distinguishable by difference in height, but a glance serves to distinguish them by their appearance. As regards the distinction of the different percentages, from $\frac{1}{4}$ to 6, no difficulty has presented itself either in the laboratory tests in the test-chamber or underground, in the hands of officials. It is true that the caps are all smaller than those shown by the Pieler lamp, but they are quite large enough to give easily appreciable differences to the unaided eye, and when viewed against the special gauge in this lamp they can be noted with certainty by any one. The Pieler caps are unnecessarily large, and are very seriously hindered from being properly seen by the fact that they are viewed through metallic gauze, and with a most unsuitable gauze background; whereas in the hydrogen-oil lamp the caps are viewed through transparent glass against a dead-black and most suitable background. The standard hydrogen lamp could be set to its standard height with absolute certainty in any part of the pit, and did not require to be taken into fresh air for adjustment. This had been secured by always setting the flame to its standard height in the presence of the gas in the test-chambers, and then reading the cap-height which was registered on the gauge and the scale-card for use in the pit. For low percentages of gas this was, however, unimportant, since the hydrogen-flame, when set

in air free from gas, did not appreciably increase in size until more than 3 per cent. of gas was present in the air. For detecting percentages of gas above 3, the use of the reduced oil-flame (also set in the presence of the gas) was recommended. Dr. Bedson was in error in stating that a volatile oil was used in the hydrogen-oil lamp. The oil burnt was a mixture of colza with water-white paraffin; the latter was not volatile, and was considered to be a perfectly safe oil in any form of lamp. The paraffin was introduced to prevent charring and crusting of the wick, and thus to improve the burning and the ease of reduction of the flame by drawing down the wick, it also improved the light of the flame. As regards the testing of the lamp in mine-gas as well as in artificially prepared marsh-gas, it should be remembered that in the preparation of a scale for the lamp, known percentages of marsh-gas must be employed, and this is most readily and certainly secured by mixing methane with air in known proportions. Carbonic acid is the only gas likely to affect the cap, and special experiments in the test-chamber have shown that even 5 per cent. of carbonic acid does not affect the cap. The precaution, however, has been taken of making tests side by side in the main return airway with the hydrogen-oil lamp, the Pieler lamp, and the Liveing indicator, with the result that, in percentages of gas ranging from $\frac{1}{4}$ to 2, the indications of the three instruments were absolutely identical. Dr. Clowes wished further to state that in comparative tests in low percentages of gas made with the hydrogen lamp and with the Pieler lamp, the caps were easily read in the hydrogen lamp, but they were not readable in the Pieler lamp furnished by an English firm. This defect was partly due to the luminosity of the large alcohol flame, but largely to the interference caused by the metallic gauze. The brass gauze partly acted by impeding the passage of the light of the faint caps, but mainly by its reflecting power. Some improvement was noticed when the gauze was blackened. But only on the removal of the bonnet and gauze were the tall caps satisfactorily seen in their full dimensions.

The PRESIDENT proposed a vote of thanks to Mr. Palmer for attending to explain the use of the testing-lamp. He hoped something

practicable would before long result from the various instruments which were brought forward from time to time, and this lamp certainly seemed to tend towards the object they wished.

The vote of thanks was unanimously adopted.

The following paper was taken as read :—"The Choice of Coarse and Fine-crushing Machinery and Processes of Ore Treatment," by Mr. A. G. Charleton.

THE CHOICE OF COARSE AND FINE-CRUSHING MACHINERY AND PROCESSES OF ORE TREATMENT.*

By A. G. CHARLETON.

PART III.—SILVER.

WET AND DRY PAN-AMALGAMATION AND LIXIVIATION.

Pan-amalgamation, as applied to silver ores, is always preceded by stamping the ore in a battery. If conducted wet, the pulp is collected in tanks, from which it is shovelled into the pans (an arrangement which might, the writer thinks, be improved upon), or else, if arranged on the Boss system (much in fashion lately owing to the saving in labour and other advantages claimed for it) the pulp is run straight through a series of pans without any intermediate settling. If conducted dry, the ore is taken direct from the cooling-floor of the roasting furnace (which forms an essential part of the plant), and is charged into the pans afterwards.

Pan-amalgamation is most extensively used in the Western States of America for the extraction of silver from its ores, and with such exceptions as have been or will be alluded to, is, the writer thinks, likely to retain its position for some time to come.

It broadly divides itself, as will be presently seen, into:—

1. The Washoe process, in which the ores go direct from the tanks to the pans wet, the amalgamation being generally assisted by the use of chemicals, chiefly salt and bluestone.
2. The Reese River process, in which the ore must be first dried: (*a*) on a drying-floor heated by waste-steam or furnace gas; or (*b*) in revolving drying-cylinders or shelf-kilns, which are steadily coming more into fashion. Roasting (usually with salt, which is mixed in the battery, or between it and the furnace) follows drying, and the ore is ground in pans in the same way as in the wet process.
3. The continuous Boss process.

* *Trans. Fed. Inst.*, vol. iv., pages 233 and 351.

THE WASHOE PROCESS.

In an ordinary wet-crushing silver mill, the ore is brought in cars to the top of the mill-building, where it is dumped over the top of the inclined grizzly or screen on to the crusher-floor. All the small pieces pass through the grizzly into the ore-bins below. The coarse rock is shovelled into the jaws of the rock-breaker, which are on a level with the crusher-floor. The ore crushed to walnut size in passing through the rock-breakers falls into the ore-bins, and thence goes to the automatic feeders (behind the stamps), passing through inclined shoots controlled by gates. The automatic feeders being kept full, ensure a uniform supply of stone being fed to the stamps as fast as needed.

The finely stamped ore, known technically as pulp, suspended in water, flows into large settling-tanks, where the excess of water is drawn off, while the thick pulp remaining is shovelled in regular charges into a row of amalgamating-pans, in which it is ground for several hours, first with salt, bluestone, and other chemicals, and afterwards amalgamated with mercury, with the mullers raised. The contents of the pans are run into large settlers (when the previous operation is finished) placed below, and in front of the pans, in which the pulp is thinned by additions of water and gentle agitation, and all the quicksilver with the precious metals in the form of amalgam, settles to the bottom. The pulp is gradually drawn off from the settlers (through holes fitted with plugs at different levels in the side) and flows to waste. The amalgam is strained from the excess of quicksilver, retorted to drive off what remains, and the resulting gold and silver cake is melted into bars. The gold and silver contained in the sulphides, which will not yield to the above treatment, is sometimes caught by concentrators (Frue or Embrey) which receive the waste pulp-tailings from the settlers. A clean-up pan generally forms part of the plant.

The old method usually employed in silver-milling was to crush coarse in the battery and grind fine in the pan, but as this involves greater power, greater wear of castings, greater loss of mercury, and not always better results, the system of crushing fine in the battery (keeping the shoes barely off the dies) has lately come into practice. By this means more gold and silver will sometimes be extracted, since ore will naturally break where there is most mineral, and the fine comminution in the battery will generally disengage most of it, the consequence being, that as quicksilver has a preference for gold and silver, it will amalgamate with them, rather than take up base metals (which render it inactive), which it is forced to do by excessive grinding.

The modern amalgamating-pan is a growth from the old arrastra, and though its construction is quite simple it presents a variety of forms. The pan holds from 1 and $1\frac{1}{2}$ to 2 tons of pulp, and generally revolves at about 60 revolutions per minute; the gearing underneath is open and plain, the muller is raised by a left-hand screw on top, the hand-wheels of which should be large (the jam-wheel being no smaller than the screw-wheel), as it frequently requires a greater application of muscle than the latter, and when the machinery is in fast motion it is inconvenient to adjust a small wheel under a large one. The most important feature of the pan is the pulp-current, which often receives but little attention, and though simple in principle is not always understood, and its neglect may cause serious loss.

These currents must be uniform and regular to ensure uniform work, and strong enough at the bottom of the pan to carry the quicksilver. The motion of the muller makes a current by throwing the pulp to the outside as it advances, which then rolls up at the side and falls over towards the centre, and down through the central opening, in and under the muller, to be thrown outwards again from the bottom. This so far cannot be improved upon, but the wings are needed, to give the pan capacity (by preventing the pulp from running too high up at the side), to accomplish which, they should have the shape of an inverted ploughshare.

Having naturally a good current above the muller, we have only to work in unison with that underneath it, which will depend on the design of the muller and setting of the dies.

The pans vary in diameter from 4 feet to 5 feet 6 inches, and have generally a cast-iron flat bottom with wooden sides. They ordinarily hold 1,200 to 1,300 lbs. of ore, and three is the usual number allowed per battery of five stamps, but sometimes two will be found sufficient. Each pair of pans requires one settler. In some districts copper plates are introduced into the pan, and much of the amalgam is found attaching to these, but the more usual system is to employ settlers entirely for the collection of the quicksilver and amalgam, after the pans are discharged. While the pulp is being worked in the pans, which usually takes 6 to 8 hours, steam is introduced to heat the mass and promote the chemical reactions; sometimes live steam is introduced direct from the boilers into the charge, but more commonly the pan is furnished with a false steam-bottom, and heated with the exhaust from the engine. The bottom of the pan is protected by cast-iron dies, and the muller is furnished with adjustable shoes, so that the wearing surfaces are renewable if it be necessary to grind the ore. The shoes and dies can be brought together when grinding by means of the hand-wheel, and

screws on top of the spindle, or the muller can be raised above the dies for circulation and mixing only.

The screw on the settler-driver, should, unlike the pans, be right-handed, for besides being more convenient in case of a belt slipping, the power applied to turn the screw, helps the muller to revolve. A settler should never be allowed to foul by an accumulation of heavy matter at the bottom, it is a positive preventive of good work. It is, however, easier to advocate this than to do it. An apparently natural remedy, viz., a liberal use of water, tends rather to aggravate the difficulty; there is a point in the thinning when the quicksilver will be precipitated, but the heavy sand be held in suspension.

If, after the charge is run out (which should leave about 8 inches of pulp in the settler), a pan is drawn and no water is added for half an hour, the warm charge will gather and carry the heavy sand; now enough water only is added to reduce it to the appearance of still some thickness, and this is all the water that is used in the charge. A horn spoon will show its success in advance of results.

Settlers are generally made with wooden sides 8 feet in diameter inside the staves, an automatic syphon-tap being provided for the discharge of the quicksilver and amalgam. Around the bottom a groove is cut, starting from nothing on one side, and gradually deepening to the syphon-tap opposite, in which all the quicksilver is carried to the outlet.

The muller-plate attached to the driver-arms, is shod with wooden plough-shoes, which are sometimes, however, attached direct to the arms themselves. The speed of the settler is generally about 15 revolutions per minute. Concentrators for a silver-mill must of necessity be simple and capacious. Good agitators (shovelled out often) are profitable. In some cases sand sluices are very effective, consisting of a broad sluice 20 to 24 inches wide, in which at intervals of 8 or 10 feet vertical strips are fixed at the side to hold movable riffles. The riffles (battens of wood) are laid in, and the sands run over them for a time (say one or two hours), when another course of riffles $\frac{1}{2}$ inch thick or less is laid on the first ones.

This is repeated until the sluice is full, when it is shovelled out, meantime allowing the sands to run through a duplicate sluice, at the side. Such sluices should have a grade of about $3\frac{1}{4}$ inches per rod to keep them under control, as by starting with a thin riffle at the bottom a strong current may be produced, whereas the introduction of a thick riffle will give a deadened current.

These sluices are an advantage where blankets are profitable, and if followed by blankets relieve the latter from much coarse, heavy material.

A blanket sluice should have a grade of about 3 inches in 7 feet. The stock of mercury in a silver-mill should be large to begin with. In a dry-crushing silver-mill the loss is usually from $\frac{1}{2}$ to $\frac{3}{4}$ lb. per ton of ore. A 10 stamp mill usually requires from 200 to 250 lbs. of mercury per month to make up the loss. The quantity needed in stock depends on the richness of the ore, but is approximately 1,500 lbs. in the pans, 1,500 lbs. in the settlers and in circulation, and 1,500 lbs. locked up in amalgam, so that a total stock of 2 to 3 tons would be necessary for starting with.

ROASTING MILLING.—THE REESE RIVER PROCESS.

After passing the rock-breaker, the ore is dried by passing through a continuous revolving-drier or shelf dry-kiln beneath the breaker, the dried ore being taken by car or else run through shoots (lined with sheet iron and regulated by gates) to the automatic feeders, if the fall admits of it. The stamps are fed while the ore is still hot, the pulverized product being conveyed to the elevator, by which it is carried to the iron storage-hopper of the roasting-furnace. In the furnace the ore, with the addition of common salt, is desulphurized and chloridized, thus preparing it for the pans and settlers. After roasting, the ore is spread on a cooling-floor, and is taken in cars as required to the pans. Amalgamation follows on the same plan as in wet crushing-mills. In old type mills it was formerly the practice to employ drying-floors of boiler or cast-iron, from which the ore was shovelled to the stamps, in place of the more modern arrangement of an automatic revolving-drier.

THE BOSS PROCESS.

This process marks a new epoch in the milling of silver ores in the United States and in Mexico, as it presents claims to superiority in many respects over the old system of pan-amalgamation. The large saving in labour and fuel, increased cleanliness, reduced wear and tear, and other features that will be mentioned later on, combine to make it a favourite with mill-men. It does away with the large pulp settling-tanks and consequent shovelling and handling of the pulp, which is a serious item of cost in ordinary wet treatment; it saves the erection of the tanks and the space they occupy; and no slum-pump or agitators are required.

The buildings and cost of erection for a continuous mill are less expensive than for an ordinary one, as they require less grading and retaining-walls and cover less area. The ore passes through the grizzly and crusher in the usual manner and down the automatic feeders to the stamps. The pulp flows from the battery through pipes to the special

grinding-pans (the product of ten stamps passing through two in succession). The pulp is then conveyed by pipes to the first amalgamating-pan, and flows continuously through the lines of pans and settlers. The tailings are run off and led over concentrators. A special feature of this process is that the pulp in the amalgamating-pans is always kept thin, instead of being about the consistency of thick cream, as usual in the ordinary pan process. The quicksilver is charged to the pans by means of pipes from the distributing-tank, and the amalgam flows direct to the strainer. The chemicals are supplied to the pans by two chemical-feeders. Steam syphons are provided for cleaning out the pans, and for conveying the pulp past any pan when it is necessary to cut it out of the series for repairs. The main-line shafting runs directly under the pans and settlers, each of which is driven from it by a friction-clutch. This arrangement of separate clutches for each pan and settler is very convenient, as any number or any one pan and settler can be stopped in case of accident for cleaning out, without having to stop the whole line.

All the water from the batteries must pass through the pans, so that all the slimes are treated; there is less loss of mercury and a true sample of the tailings can be obtained, a matter of much greater difficulty with the old method. Heating by exhaust steam is stated to be one of its economical features, obviating any strain upon the pan, which is heated indirectly through the hollow steam-bottom. Where changes were made from live to exhaust steam in some mills it is said to have saved as much as £2 10s. 0d. to £3 2s. 6d. per day for cord wood.* By using special grinding-pans, the ore can be crushed through a coarser screen in the battery, and the finer grinding can be afterwards accomplished in the pans, thus obtaining increased capacity.

Though it does not pretend to cope with rebellious ores which are unsuited to such treatment, the Boss process is without doubt a great improvement over ordinary pan-amalgamation in tanks. If the latter process be employed, the tanks are filled in succession; the pulp being conveyed to them through a launder, by means of which the supply is cut off as each vat becomes full. Arrangements should be made to settle as much of the mineral as possible by allowing the water to circulate through the empty tanks before passing to the slum-pit outside, the escape or tailings water being turned into each tank after emptying it of sand. Each tank in turn thus receives the water after passing through the other tanks, and becomes the final one of the series. In some mills a certain number of tanks are kept employed in settling the sands, while the

* Messrs. Fraser-Chalmers, *Catalogue*, No. 4, page 82.

remainder are used up for the slimes; in others the capacity of the vats is large enough to settle the sands and slimes together. Before charging the pulp into the pans it is usually shovelled into heaps on the platform in front of the pans, which is slightly inclined towards the tanks to drain the water back into them. In the pan-treatment a proper consistency of the pulp, a proper degree of heat, and clean quicksilver, are matters of the chiefest importance.

While charging the pan the muller for grinding is kept revolving and lowered, water having been previously run in so as to fill the pan to within 12 to 18 inches of the edge, and heated with steam. Some mill-men favour direct heating with live steam, others by means of a jacket or false bottom. The charge must be heated nearly to boiling-point by turning on steam again during the grinding. At the commencement of the grinding the pulp is thin, but after a couple of hours it will acquire the proper consistency for receiving the quicksilver, which becomes diffused (by the heat and grinding) in small globules through the mass. The pulp should be thick enough to cling to a wooden paddle dipped in to test it, showing particles of mercury evenly disseminated through it, so that the charge will carry the quicksilver in suspension. The salt (say about 10 lbs.) is added as soon as the pan is charged, and 2 lbs. of sulphate of copper (or whatever proportion is used), half an hour later. After the pulp is heated to about 180 degs. Fahr. steam is cut off, and the muller should be lowered gradually during the progress of grinding. When finished (after about 2 hours), some 200 lbs. of mercury are added to a 1,200 lbs. charge of pulp. The grinding is then sometimes continued for another half-hour or an hour, when the muller is raised and the pan run with the muller up, for 3 hours more. There is, however, less chance of flowering if the bulk of the mercury is not added until the grinding is entirely finished. A quarter of an hour before drawing the charge, sufficient water is added to fill up the pan, thinning the pulp thoroughly, so that it will flow readily out of the pan, and cooling it.

The work should be so arranged as to charge and discharge a pan every 6 hours, which gives it a capacity of about $2\frac{1}{2}$ tons. The pans should be discharged in succession, not all simultaneously; that is to say, as soon as one or two pans have been discharged and refilled, after a certain interval (depending on the number of pans in the mill) the next pan or two should have completed their 6 hours' work, and be ready to undergo the same process.

When discharged, a stream of water should be directed into the pans,

to rinse them out thoroughly. Everything thus flows to the settlers, and through the partial dilution of the pulp, the quicksilver settles to the bottom, and is collected in the syphon. During the discharge of the pans the settler arms are kept revolving, and after a short interval a spray of water is turned on, and allowed to run till the settler is full. It is then turned off and the muller is allowed to revolve for an hour. This allows the quicksilver to collect and settle. An abundant stream of cold water is then let in and the settler is allowed to discharge through the different plug-holes, commencing with the top one, the operation being timed so that the bottom hole is reached just in time to receive the next charge. Once a week or oftener the settlers should be cleaned out, and the coarse sand and sulphides accumulating in the bottom are re-worked in the pans. Generally two settlers discharge into one agitator, and a constant stream of water should run into them. They collect some coarse sand containing a little quicksilver, amalgam, sulphides, and a quantity of iron which is worked-up in the clean-up pan. The floors should be kept as clean and free from dirt as possible. All drains should lead into the agitators, and unless the weather is too cold the quicksilver floor should be sluiced down with a hose daily.

RETORTING AMALGAM.

The retorts for retorting silver bullion are generally cylindrical or square with the corners rounded off, and containing shelves for several iron dishes. They should be heated to a bright cherry-red heat before commencing the retorting, otherwise it is difficult to drive off the last traces of quicksilver. A serious loss is entailed by a retort bursting, not an uncommon occurrence even with the greatest care. They must therefore not be fired too strongly, and must be strongly made and well braced. The mercury fumes are condensed by condensers acting on the Liebig principle, the quicksilver being caught in a bucket of water, into which the end of the pipe from the retort dips; care being taken that the water is not able to run up into the retort as it cools by the end of the pipe being too deep under water. After the retorting is finished it is advisable to leave the retorts to stand for several hours before withdrawing the bullion.

For cleaning quicksilver from impurities, which become mechanically mixed with it, the quicksilver strainer invented by Mr. H. H. Oakes is recommended by Mr. Eissler and is described by him in detail.*

* *Metallurgy of Silver*, page 159.

GENERAL REMARKS, ORES, ETC.

The ores of silver which can be successfully treated by the Washoe process are those in which the metal occurs in a condition which will be acted on by quicksilver, assisted by heat, agitation, and certain chemicals (chiefly salt and sulphate of copper), which produce a certain quantity of sub-chloride of copper, through the secondary action of the metallic iron present. The chloride and sub-chloride of copper (both of which are liable to be formed), tend to reduce any sulphides of silver present, by exercising a chloridizing influence upon them, and at the same time decompose the sulphides of lead and zinc. The sulphate of copper, moreover, enhances the amalgamating energy of the mercury by tending to expel the lead, and by causing the formation of a small quantity of copper amalgam.

A list of the chief ores and minerals containing silver would comprise the following :—

Name.	Composition.	Per Cent. of Silver when Pure.
Naumannite	Ag_2Se	73·2
Eukairite	$\text{Cu}_2\text{Se} + \text{Ag}_2\text{Se}$	43·1
Hessite	Ag_2Te	62·8
Petzite	$(\text{Au Ag})_2\text{Te}$	41·8
Sylvanite	$(\text{Au Ag})\text{Te}_2$	10 to 15
Argentite (silver-glance)	Ag_2S	87·1
Stromeyerite	$\text{Ag}_2\text{S} + \text{Cu}_2\text{S}$	53·1
Sternbergite	AgFeS_2	34·2
Miargyrite	$\text{Ag}_2\text{S} + \text{Sb}_2\text{S}_3$	36·7
Pyrargyrite	$3\text{Ag}_2\text{S} + \text{Sb}_2\text{S}_3$	59·8
Proustite	$3\text{Ag}_2\text{S} + \text{As}_2\text{S}_3$	65·4
Stephanite	$5\text{Ag}_2\text{S} + \text{Sb}_2\text{S}_3$	68·5
Brogniardite	$\text{PbS} + \text{Ag}_2\text{S} + \text{Sb}_2\text{S}_3$	26·1
Polybasite	$9 (\text{Ag}_2\text{Cu})\text{S} + (\text{Sb As})_2\text{S}_3$	68·0
Tetrahedrite (Fahlerz)	$(\text{CuAg})_2\text{S} + (\text{Sb As Bi})_2\text{S}_3 + (\text{Fe Zn Hg})\text{S}$	variable.
Xanthoconite	$(3\text{Ag}_2\text{S}, \text{As}_2\text{S}_3) + 2 (3\text{Ag}_2\text{S}, \text{As}_2\text{S}_3)$	64·00
Fire blende	AgSbS	62·3
Freieslebenite	$\text{Pb}_2\text{Ag}_3\text{Sb}_2\text{S}_8$	23·8
Cerargyrite (horn-silver)	AgCl	75·33
Bromyrite	AgBr	57·40
Embolite	$\text{Ag} (\text{Cl Br})$	61 to 71
Iodyrite	AgI	46
Native silver ... ..	... ..	100·00
Arquerite (native amalgam)	AgHg	34·8
Electrum (native alloy of gold and silver) ... ..	... ..	27 to 32·7

Minerals, etc., often containing silver in small quantity :—

Galena	PbS
Blende	ZnS
Pyrite	FeS ₂
Chalcopyrite	CuFeS ₂
Erubescite	Cu ₂ FeS ₃
Mispickel	FeS ₂ + FeAs ₂
Altaite	PbTe
Clausthalite	PbSe
Nagyagite	(Pb Au Ag) (Te, S) ₂
Chivialite	(Cu ₂ Pb) S + $\frac{1}{2}$ Bi ₂ S ₃
Dufrenoyite	PbS + As ₂ S ₃
Enargite	3Cu ₂ S + As ₂ S ₃
Cupel bottoms, dross litharge sweepings, etc.	
Slags, etc.	

The presence of sulphides of iron, copper, lead, zinc, and antimony, interferes with the success of the amalgamation process in several ways. They foul the amalgam and check the reactions of the chemicals on the free-milling minerals, and carry off in their refractory combinations a portion of the silver which the latter contain. It often happens that while the upper decomposed surface-ores of a vein are free-milling, as depth is attained (beyond the decomposing action of the air and surface waters) they change in character, through sulphides and base metals making their appearance in the ore.

Occasional natural deposits of chloride of silver and some rare instances of native silver, unaccompanied by sulphides, form, with certain decomposed ores, the chief types adapted to free-milling; though the process being cheaper than roasting-milling, ores are sometimes worked by it, which should properly be roasted, but the percentage saved in such cases is correspondingly low. Ores carrying quite a large percentage of base minerals may be worked by roasting-milling, but in many cases it is more profitable (when the conditions admit of it) to treat such ores by concentration and smelting. The presence of certain minerals in combination may render the chloridizing roasting of an ore extremely difficult. The Silver King mine in Arizona may be cited as an instance of this, as mentioned by Mr. Aaron.*

The ore in question consisted largely at one time of fahlerz, chlorides, bromides, and oxides, in a gangue of quartz and heavy spar, and being of high grade it proved well adapted to treatment by the Kiss lixiviation process, for which it had to undergo a preliminary chloridizing roasting.

It was found that this ore sustained a serious loss of silver by volati-

* Report of the Director of the United States Mint.

lization during roasting ; an extra draught produced by opening both ends of the fireplace somewhat mitigated the difficulty, but it was only finally overcome by introducing steam into the furnace (as originally suggested by Dr. Percy) which successfully met the difficulty ; the volatile metal chlorides (to which the volatilization of the silver is mainly owing) being decomposed and converted into oxides, with the instantaneous production of hydrochloric acid. Unfortunately, however, as depth was reached in the mine the character of the ore changed. The proportion of chloride and tetrahedrite fell off, and zinc blende and galena became more abundant, and this led to far more serious difficulties.

The roasting became slow and tedious ; while previously a charge of 5 tons could be well roasted in 14 to 16 hours, converting about 95 per cent. of the contained silver into chloride. The percentage of soluble silver in the roasted ore decreased also somewhat, causing richer tailings, and as the grade of the ore likewise fell off, a serious diminution in the output of bullion ensued. The ore, moreover, developed a tendency to ball and form crusts on the furnace walls. The balls were peculiar, being perfectly spherical and of all sizes from a pin's head to a marble, extremely hard, and consisting of concentric layers. The ore being crushed wet and received into settling-pits, no doubt operated disadvantageously in this instance.

When the ore was by no means at its worst, analysis showed it to contain 12 per cent. of zinc—equivalent to about 18 per cent. of blende, 6 per cent. of lead as galena, a good deal of antimony, a little arsenic, a very little iron and copper, and trifling quantities of cadmium, selenium, tellurium, and bismuth. The conjunction of antimonial and plumbiferous minerals with zinc blende tends in fact to make roasting difficult. The character of the gangue also exercises a great influence on the roasting. The presence of quartz is advantageous, spar or gypsum is not troublesome, but earthy carbonates are detrimental, and magnesia bad.

At one time the ore contained less quartz and spar than formerly, and more of the so-called porphyry of the district, which contains magnesia in abundance.

In the case of ore which balls in the furnace when roasted with salt, the usual practice is to roast without salt, to a certain stage when the salt is added and the heat increased ; but the presence of metallic silver and the absence of a fair proportion of iron rendered this method inapplicable.

The next idea tried, that of roasting to complete oxidation without salt, and then chloridizing by an addition of calcined copperas and salt, has been used with a slight modification on some of the worst ores with good results.

Another successful plan was to mix a certain proportion of sand, about 7 per cent., with the charge. The sand used contained a little silver, being the coarser portion of a pile of rather rich tailings from previous concentration. The addition of one-third of clean quartzose silver-ore was found to act favourably, 95 per cent. of the chloride being got out in 24 hours with 3 ton charges.

Mr. Stetefeldt has lately introduced the plan of drying and roasting ore with gas, at the Holden mill, Aspen, Colorado, and at the Marcac mill, Park City, Utah, where lixiviation is employed for the treatment of the ore. The former plant was put in operation in November, 1891, and consists of four double shelf-driers, with one 6 feet diameter Taylor revolving-bottom producer, and one large Stetefeldt furnace, with a Taylor producer, also 7 feet in diameter. Mr. Morse, the general manager of the Holden works, states that, on a recent run of 4,631 tons of ore, 96·4 lbs. of coal were used per ton of ore roasted, costing 14·45 cents. The coal, consisting of a mixture of about equal proportions of Colorado Newcastle and Sunshine coal, costing 3·00 dols. per ton delivered at the mill. The composition of these coals are :—

			Fixed Carbon. Per Cent.		Volatle Matter. Per Cent.		Ash. Per Cent.		Water. Per Cent.
Colorado Newcastle	...	...	I. 55·9	...	35·9	...	5·4	...	—
" "	...	...	II. 48·6	...	37·95	...	11·6	...	1·7
" Sunshine	...	...	III. 48·0	...	43·0	...	7·5	...	—
" "	...	...	IV. 37·1	...	36·3	...	23·8	...	2·8

This, Mr. Stetefeldt states, is the cheapest drying and roasting on record in any silver-mill, and the introduction of the system of employing gas producers is making rapid progress in silver-milling. Full details of the cost of drying and roasting at Aspen on a run of 12,000 tons of ore are given in the *The Engineering and Mining Journal*, New York, of June 25th, 1892.*

When ores contain a very large percentage of sulphur : *i.e.*, are exceptionally heavy. Mechanical roasting furnaces cannot, as a rule, compete with the old-fashioned reverberatory furnace, but, with a moderate amount of sulphur, many of them give excellent results. The cost of roasting (chloridizing) in the Stetefeldt furnace is said to vary from 16s. to £1 0s. 10d., and the furnace is said to cost £625 to build. A Brückner furnace, which is a favourite in small mills, will treat from 3 to 4 tons (in exceptional cases 10 tons) in 24 hours. The cost of roasting in it varies from 10s. to £1 per ton. An improved form, with double cylinders set tandem, is estimated to roast 20 to 40 tons of refractory ore (in inverse proportion to the percentage of sulphur it carries) at a cost

* Page 660.

of £4 3s. 4d. per day, *i.e.*, 2s. 1d. to 4s. 2d. per ton. Mr. Brückner's estimate of the cost of a double-cylinder plant is £2,255 erected.

In many of the best modern mills where dry-crushing is practised the furnaces are placed at the extremity of the battery line, a little behind it, and not in front, as they used to be.

Mechanical furnaces of the improved Brückner and Howell-White type (a modification of a Hocking and Oxlands calciner), and the Stetefeldt and O'Harra are amongst those in most general use.

If the ore requires roasting, dry stamps are invariably used, the mortars being covered in with a wooden housing, to which exhaust fans are attached to draw off the dust into pockets (emptied at intervals), and the dry ore is moved by screw-conveyors or horizontal endless-belt tables to the feed-pocket of an elevator, which raises it to the hopper of the furnace if a mechanical roaster be employed.* When the ore is roasted a chlorination assay† must be made of every charge.

The floors of modern wet-crushing mills are laid slightly inclined towards a reservoir connected with the pulp-tanks, double-planked and tarred, and the mill supply of quicksilver is almost always handled mechanically by a mercury pump. It is imperative, however, that it should be of first-class make, as a poor device for handling quicksilver is more extravagant than hand labour.

The variations in the details of the plant and method of manipulation are capable of so great a number of permutations that it would be useless to attempt to go into the subject fully in this paper. The author should, however, state that the fineness to which the ore can be reduced is to no small extent determined by the capacity of the settlers to work off the coarse sands without loss of mercury.

Although it has been found by experience that some ores roast as well if crushed through a 30 as they would through a 40 mesh screen; some heavy ores, *i.e.*, those that contain a great deal of sulphur, give a low chlorination and extraction, unless crushed finer, say to a 50 mesh. The limit of coarseness to which it is ordinarily practicable to carry crushing with stamps is, the author believes, about 30 mesh.

* A new form of elevator and conveyor made by the Jeffrey Manufacturing Co., of Columbus, Ohio (a description of which is given in *The Engineering and Mining Journal*, New York, of March 4th. 1893, page 201), consisting of a steel cable, to which a number of iron diaphragms of suitable shape are attached at intervals, which travel in a trough of corresponding shape, would seem to be particularly applicable to this purpose.

† The method of doing this is excellently described by Kustel, *Roasting of Gold and Silver Ores*, second edition, 1880, page 32, *et seq.*

It cannot be too strongly emphasized that one of the most important points in pan-amalgamation is cleanliness about the works, and the use of clean quicksilver; though order and neatness, with the polish that comes of the use of elbow-grease, are factors of economy that ought to be naturally looked for in all mining plant.

Bichloride of copper is supposed to be the active agent in the Washoe process in the reduction of sulphide of silver; just as bichloride of mercury* attacks gold and amalgamates with it when ordinary quicksilver will not touch the yellow metal.

If it is worth while putting up a well-constructed mill building (which cannot be done without corresponding expense) it is worth while keeping it in first-class repair.

The cost of an ordinary 20 stamp dry-crushing plant, including rock-breaker, mechanical-drier and roasting-furnace, cooling-floors and elevators, with stamps and conveyors, and the necessary pans, settlers, sluices, etc., with a quicksilver-tank system, will not, in most cases, fall far short of £7,100, in London, exclusive of local freight and erection charges. It would weigh about 284 tons.

The cost of a 20 stamp wet-crushing silver-mill plant, with rock-breaker, automatic-feeders, stamps, pulp-tanks and pans, settlers, etc., will not generally come to less than £6,525, and weigh about 186 tons.

The cost of treatment, milling ores wet, varies from 12s. 6d. to £1 17s. 6d., employing the Washoe process. A high average being about 18s. 9d. per ton.

The cost of treatment, milling ores dry†, varies from £1 5s. to £2 11s., and when the ore requires roasting it will average from £1 13s. 4d. to £3 2s. 6d., and sometimes as high as £5 16s. 8d. per ton.

The great variations in silver ores, conditions of working, and methods of extraction make it impossible to give more than very general estimates of cost, as it fluctuates frequently in the same district, with differences in price of fuel, labour, freight, chemicals, etc.

* The Designolle process.

† The writer alludes here to a modification of the Reese River process, which dispenses with roasting; as examples of which, we have the Eberhardt at White Pine, and the Lancaster mill at Tuscarora. It is practised on the grounds that a much higher percentage is saved, if the ore contain chlorides, as the finely divided horn-silver is likely to be lost if crushed wet, although the slimes are thin. It is applicable also to some ores which produce an excessive amount of slime, which escapes the settling-tanks.

A 25 stamp wet-crushing silver mill, running 24 hours, generally needs the following crew of men :—

2 rock-breakermen.	1 mechanic.
2 battery feeders.	1 foreman and assayer.
2 amalgamators.	2 assistant amalgamators.
2 engineers (and in some cases 2 firemen).	3 tank-men.

The Grand Prize* (a 20 stamp dry-crushing and chloridizing mill) employs :—

No. of Men.	Wages per 12 Hours Shift.			
	£	s.	d.	
2 amalgamators	at	1	0	10
2 „ helpers	„	0	16	8
2 chloridizers	„	1	0	10
2 „ helpers	„	0	16	8
2 battery feeders (tenders)	„	1	0	10
2 engineers (drivers)	„	1	0	10
4 firemen	„	0	16	8
1 melter and retorter	„	0	16	8
6 dry-kilnmen	„	0	16	8
1 blacksmith	„	1	0	10
4 labourers	„	0	16	8
28				

The Lancaster* (a 10 stamp dry-crushing raw-amalgamating mill) employs :—

No. of Men.	Wages per 12 Hours Shift.			
	£	s.	d.	
2 amalgamators	at	1	0	10
2 „ helpers	„	0	16	8
2 battery tenders	„	0	16	8
2 engine drivers	„	1	0	10
3 firemen	„	0	16	8
2 dry-kilnmen	„	0	16	8
3 labourers	„	0	16	8
16				

EXAMPLES OF THE WASHOE PROCESS.

The ores of Mineral Hill, Nevada, consist of chloride of silver, bromide of silver, argentite, polybasite, stephanite, carbonate and molybdate of lead, carbonate of copper, and some manganese, occurring in a limestone-formation in irregular deposits. Mr. Eissler† states that, being of a complex character, they were originally treated by roasting milling, but he

* Egleston, *Metallurgy of Silver*, page 437. † *The Metallurgy of Silver*, page 155.

subsequently worked them successfully on the Washoe principle by dry-crushing and amalgamation (the modification of the Reese River process, before alluded to).

A point of special interest is the presence of bin-oxide of manganese in the ore. This mineral appears to have a deleterious effect on the amalgamation, its presence being indicated in the settlers by a thick froth, which in spite of dilution with water, carried off flowered quicksilver. The charge, Mr. Eissler states, which gave the best results, was found to be 1,500 lbs. of ore mixed in the pans with 15 to 20 lbs. of salt and 3 to 5 lbs. of bluestone. Treating 18 tons per diem, the cost was as follows:—

	£	s.	d.
Superintendent, who also acted as assayer	2	1	8
Master mechanic	1	5	0
Carpenter	1	5	0
Two engineers at £1 0s. 10d., 1 day and 1 night ...	2	1	8
Two men tending rock-breaker at 16s. 8d.	1	13	4
One man at dry-kiln, and to take battery samples, 1 day and 1 night	1	13	4
Two battery-feeders, 1 day and 1 night at 18s. 9d. ...	1	17	6
Two pan-men during the day	1	13	4
Two pan-men and one retorter at night	2	10	0
400 lbs. of salt at 3d.	5	0	0
8 cords of wood at £1 5s.	10	0	0
Loss of mercury, 30 lbs. at 5s.	7	10	0
Wear and tear of iron, and repairs	4	3	4
Oil and incidentals, sulphate of copper and assay materials	3	2	6
	£45	16	8

Cost per ton, £2 10s. 11d.

The ores of Pioche, Lincoln County, Nevada, which contain on the average 3 to 5 per cent. of lead (cerussite and galena) have been treated successfully by the ordinary Washoe process, the ore being worked up to over 82 per cent.; when assaying £27 1s. 8d. per ton and yielding bullion, the average fineness of which was somewhat below 700, containing lead and some copper.

To extract the greater part of the lead, the quicksilver and amalgam after leaving the settlers was strained in sacks suspended in a large box filled with water, heated with steam by a $\frac{1}{2}$ inch pipe. Lead amalgam at the temperature of boiling water remains liquid, and will therefore strain through with the excess of quicksilver. As a certain amount of silver and copper amalgam also passes through, the mercury is run into a smaller box cooled with water, and when cold strained in the usual way,

leaving an amalgam of lead containing a small amount of the other metals. This lead amalgam, when retorted, gave bullion containing 6 to 20 per cent. of silver, very little copper, and only a trace of gold. The amalgam in the first sacks gave bullion from 550 to 680 fine in silver, and finer in inverse proportion to the amount of copper in the ore.

The amalgam from the second straining of the quicksilver, with ore of normal character, gave bullion 60 to 200 fine. When the ore was amalgamated without chemicals the bullion was 300 to 350 fine, and when amalgamated with salt and bluestone, but not strained in hot water, 400 to 450 fine. The ore contains on an average £1 0s. 10d. in gold to over £20 16s. 8d. worth of silver, this proportion remaining very constant. 45 to 55 per cent. of this gold is extracted. The bullion contains 0.0003 to 0.0015 parts of gold, and occasionally as high as 0.0030 parts. With bullion 500 to 600 fine (after passing through the hot-water straining process) the loss of quicksilver amounted to $4\frac{1}{2}$ lbs. per ton of ore, due probably to the formation of chloride of lead and the subsequent formation of sub-chloride of mercury. Another source of loss was the formation of floured lead-amalgam, which had the dull appearance of lead and floated off in flakes on the surface of the water. The chloride of copper formed rapidly destroyed the castings of the pans. The proportion of retorted bullion to amalgam in working the Comstock, White Pine, and Idaho ores is as 1 to $5\frac{1}{2}$ to 6; in amalgam containing a large amount of copper as 1 to 7 to $7\frac{1}{2}$; and in very base amalgam as 1 to 4.*

The ores of the Silver Reef in the Harrisburg district, Utah, are of a remarkable character, consisting of chocolate-coloured sandstone with fine chloride of silver disseminated through its mass, and where organic remains (such as leaves and stems of trees) are found embedded in it, the silver is present in a pure metallic state. In the Stormont mine, the ore is found in a zone 10 to 100 feet thick, often associated with fossil-remains, etc., and is bounded by red sandstones above and white sandstone below. The ore is very easily crushed and disintegrated, a 750 lbs. stamp putting through 7 to 8 tons per 24 hours' crushing through a 40 mesh screen, so that 5 to 10 stamps will more than supply 12 pans, working $1\frac{1}{2}$ tons pan charges. Considering the size of the mills, the cost of milling is in consequence extremely low. The ore averages £6 5s. per ton. The tailings vary greatly in richness, according to the character of the ore. With sandstone ore, they will often carry 12s. 6d. per ton, while with shaly ore they may run £2 1s. 8d. or more.

* Eissler, *Metallurgy of Silver*, page 133.

Mr. R. P. Rothwell gives the cost of a year's working at three of the mills of the district as follows :—

Per ton of 2,000 lbs.	Christy M. and Mg. Co. 14,249 tons. £ s. d.	Stormont Co. 9,983 tons. £ s. d.	Leeds Co. In 1878 12,064 tons. £ s. d.	In 1879 4,679 tons. £ s. d.
Labour & salaries	0 11 10½	0 12 4½	0 9 2	—
Bluestone .. (2·1 lbs.)	0 1 3½	(1·¼ lbs.) 0 1 1	0 13 5	—
Mercury ... (1·22 lbs.)	0 2 5	(1·13 lbs.) 0 2 4½		
Salt (25·8 lbs.)	0 2 1½	(20·00 lbs.) 0 1 2½		
Fuel ...	0 5 5½	0 1 10½		
General supplies	0 3 7½	0 1 10½		
Incidentals ...	0 1 8½	0 0 6		
	£1 8 6	£1 1 4	£1 2 7	£0 17 2
Hauling ore to mill	0 3 0½	0 8 4	0 1 4	0 1 0½

In parts of Mexico, silver ore which falls below £6 5s. per ton is not available for the Washoe or patio processes, owing to the excessive cost of transport, and fuel. At Guanajuato, for example, packing on mules costs 14s. 7d., and treatment of the ore £2 7s. 11d., whilst mining, pumping, hoisting, etc., add a further charge of £2 10s. Wood costs £2 1s. 8d. and coal £4 11s. 8d. per ton. The district, however, is said to be a rich one, one group of mines north of the city of Guanajuato being credited with a production of 312,860,000 dollars between 1548 and 1889, out of a total of 650,000,000 dollars worth of silver obtained from the district.

Mr. W. L. Austin gives* the subjoined particulars of the cost of running a wet-crushing silver-mill in the Tombstone district, stating however that, owing to the arrangement of the plant, which works under some disadvantages consequent upon its alteration from dry-chloridizing to wet-crushing and other reasons, a reduction of 20 per cent. in the cost of milling could be effected under more favourable circumstances.

A novel feature to be noticed is that the shoots leading from the ore-breaker to the bins are not only provided with the ordinary grizzlies, the bars of which are set $\frac{3}{8}$ inch apart, but the bottom of the shoot itself is fitted with a shaking-frame covered with screens of the same mesh as those used in the battery.

This relieves the batteries materially, and decreases the amount of slimes, increasing the capacity of the mill 5 per cent. or more, depending on the fineness of the ore and its percentage of moisture, as the ore fine enough to pass the screens, goes direct to the pans without passing through the battery at all.

* "Silver Mining in Arizona." *Trans. Am. Inst. Min. Eng.*, vol. xi., page 91.

The average gross weight of the stamps is between 750 and 800 lbs. The shoes, weighing 120 lbs., have an average life of one month, when worn down to about 35 lbs.

Hendy Challenge feeders are used, and the stamps crushed 2·9 tons of medium hard rock in 24 hours for the first six months they were in operation, using a 30 mesh screen.

After 4 hours' grinding in the pans, the average extraction was found to be about 81·04 per cent., and nothing material was gained by prolonging the treatment, but by the use of salt and bluestone 87 per cent. could be got out of the ore, which contained only 7 per cent. of its silver as chloride.

So long, however, as coarse crushing was adhered to in the battery, the bullion was much debased. The remedy was found to be to crush finer, using 35 mesh screens and amalgamating without grinding in the pans, by which means the bullion was kept at ·970 fine without sacrificing the milling percentage. The ore contains about 8s. 4d. in gold, and 43 per cent. of this was also recovered. It may be mentioned that the debasing of the bullion was chiefly due to lead, which lowered it down to ·200 and ·300, and whenever wulfenite appeared in the ore this was remarked to a much greater extent than when the lead was in the form of cerussite or galena.

The average cost of milling for five months was with 20 stamps :—

	£	s.	d.
Labour	0	10	6
Fuel... ..	0	4	4½
Chemicals and mercury	0	3	2½
Lubrication	0	0	2
Illumination	0	0	1½
Castings	0	1	4½
Supplies	0	0	8
Per ton	£1	0	5

The cost of labour (subdivided) treating 1,730 tons, based on one month's work was estimated to be :—

	s.	d.
Crushing	2	2
Amalgamating	2	9½
Power-pumps, etc.	1	11½
Foremen, etc.	3	7½
Tailings-pits	0	5½
Per ton	11	0

The loss of mercury averaged about 5s. 5d. per ton, and about 0·11 cords of wood,* and 1,200 gallons of water, were consumed per ton milled.

Mr. Austin also gives another instance of the cost of wet-crushing in Arizona, estimated on 2,643 tons crushed in a 20-stamp battery, furnished with a rock-breaker and automatic feeders, separating the coarse sands in hydraulic sizing-tanks, and working each sand-class by itself, for which the ore alluded to was particularly suitable, being entirely free from base metals with a gangue of light specific gravity.

The stamps weighed 800 lbs., and put through on an average 5 tons per head in 24 hours.

Cyanide and lime, in the proportion of 14 lbs. of the former chemical and 120 lbs. of the latter per 100 tons of ore, were used in the pan treatment. The mercury was pumped through the mill for distribution.

The motive power was a 200 horse-power horizontal engine (42 inches by 20 inches cylinders, run at 60 revolutions per minute), and the boilers, which were tubular, 15 feet 6 inches by 54 inches, carrying 85 lbs. steam pressure, burnt 16 cords of wood irrespective of the boiler for the pump, which burnt 8 cords per week. The cost per ton of ore was :—

	£	s.	d.
Labour	0	5	1½
Supplies	0	7	7
Assaying	0	4	5½
	0	17	2

The cost for labour as given above is thus subdivided :—

	£	s.	d.
Crushing	0	1	1
Amalgamation	0	0	10
Power, pumps, and repairs	0	1	8
Foreman, melter, etc.	0	1	6½
	0	5	1½

The cost of material as given above is thus subdivided :—

	£	s.	d.
Mercury	0	1	9
Chemicals	0	0	3½
Castings	0	1	2½
Illumination and lubrication	0	0	3½
Fuel, including pump	0	3	3
Supplies	0	0	9½
	0	7	7

* This includes pumping the water supply 200 yards (with a lift of 100 feet vertical); 7 cords of mixed wood (black oak, white willow, and pine), costing £1 17s. 6d. per cord, were used on the average per day. The mill engine was provided with a Meyer cut-off.

The consumption of wood per ton of ore was 0.15 cords, and of mercury 0.96 lbs.

The bullion averaged .995 fine.

Stated in gallons, the quantity of water used per boiler in a silver-mill is $7\frac{1}{2}$ gallons per horse-power per hour. For each stamp, 72 gallons per hour; for each pan, 120 gallons per hour; and for each settler, 60 gallons per hour.

The consumption of wood (not including that used for roasting) in a dry-crushing mill is put by Prof. Egleston at about $\frac{1}{3}$ cord per ton.

The power required for a Brückner roasting-cylinder is estimated at about 2 horse-power, and for the Howell-White $1\frac{1}{2}$ horse-power.

The ore according to its baseness loses 3 to 15 per cent. by weight in roasting.

The value of stock on hand necessary to run a dry or wet-crushing silver-mill, including wood, mercury, castings, chemicals, etc., is very variable.

EXAMPLES OF ROASTING MILLING TREATMENT.

The ore of the Ontario mine is a very base one, being composed of zinc, lead, and silver sulphides and silver chloride in a quartz gangue. This becomes baser with the increasing depth of the workings. The bullion obtained runs about 600 fine and contains no gold. The average grade of the ore treated is 100 to 130 dollars per ton, and the amount treated varies from 50 to 55 tons per day, though formerly (when it was less base) 65 tons were handled daily. The ore is roasted in Stetefeldt furnaces with the addition of about 15 per cent. (dry weight) of salt.

After leaving the furnace the ore goes to the cooling-floor, where it remains piled up for 18 hours. This increases the chlorination from 3 to 8 per cent. After being damped it is run to the pan-room. Each pan-charge of ore weighs 2,500 lbs., to which 1 per cent. of salt is added, and the pulp made up with the addition of hot water to proper consistency. The muller makes about 65 revolutions per minute, and is held 1 inch above the pan-bottom so that it does not grind. About 1 lb. of zinc and 300 lbs. of mercury are added to the pan after it has run 1 hour (and is hot), and amalgamation is continued for 7 hours. From the pans the pulp is drawn into settlers, which run 4 hours, making 40 revolutions per minute, and after running for 1 hour cold water is let in, and the overflow discharging the tailings is set running. The mill is worked up to from 88 to 92 per cent. of the value of the ore, that being counted as the amount chlorinated. The tailings carry off 8 to 12 per cent. of the silver.

The cost of treatment on a production of 50 tons per day was stated as follows* :—

No. of Men.	Occupation.	Per Day. Dollars.	Per Ton. £ s. d.
1 ...	Foreman...	10-00	0 0 10
1 ...	Assayer ...	6-00	0 0 6
3 ...	Machinists at \$4-00	12-00	0 1 0
2 ...	Carpenters at 4-00	8-00	0 0 8
2 ...	Blacksmiths at 4-00	8-00	0 0 8
2 ...	Engineers at 4-00	8-00	0 0 8
2 ...	Foremen at 3-50	7-00	0 0 7
9 ...	Dry-floormen at 3-50	31-50	0 2 7½
3 ...	Batterymen at 4-00	12-00	0 1 0
6 ...	Roasters at 4-00	24-00	0 2 0
12 ...	Cooling-floormen at 4-00	48-00	0 4 0
4 ...	Carmen at 4-00	16-00	0 1 4
4 ...	Amalgamators at 4-50	18-00	0 1 6
1 ...	Retorter at 4-00	8-00	0 0 8
1 ...	Melter at 4-00		
4 ...	Labourers at 2-50	10-00	0 0 10
4 ...	Watchmen at 3-00	12-00	0 1 0
2 ...	Ore-floormen at 3-50	7-00	0 0 7½
3 ...	Clerks at 4-00	12-00	0 1 0
66		\$257-50	£1 1 6
Supplies.		Per Day. Dollars.	Per Ton. £ s. d.
Salt, 10 tons	at \$8-00	80-00	0 6 8
Quicksilver, 175 lbs.	at 0-50	87-50	0 7 3½
Wood, 15 cords	at 4-50	67-50	0 14 8½
Coal, 12 tons	at 8-25	99-00	0 6 3
Castings			0 1 0½
Oil and waste...			0 2 1
Sundries, chemicals, etc.			0 2 0½
Hauling from mine...			0 1 0½
Charcoal, assaying, and melting			£2 1 1½

Total cost per ton, £3 2s. 7½d., exclusive of office expenses, general superintendence, repairs, and insurance.

The report of the Granite Mountain Company, Phillipsburg, Montana, one of the largest dry chloridizing roasting-crushing plants in America (running 153 stamps), gives the following particulars of working for the year ending July 31st, 1891 :—

Ore, tons crushed, wet, 72,623	=	dry weight, 68,850
Salt, " " 10,897	=	10,645
Total		79,495

Average moisture in the ore, 3½ per cent.; average moisture in salt, 1-5 per cent.

* R. P. Rodwell, *Trans. Am. Inst. Min. Eng.*, vol. xiii, page 337.

The salt and ore are mixed before crushing.

The ore averaged 50·59 ounces of silver, and the cost of milling was 1s. 8d. per dry ton, divided as follows :—

	£	s.	d.
Labour and superintendence ...	0	14	5
Salt	0	8	3½
Fuel	0	6	10½
Mercury	0	4	8
Castings	0	2	7½
Chemicals	0	1	2½
Water	0	0	6½
Miscellaneous	0	3	0½
	£2	1	8

Equal to £1 19s 5½d. per wet ton.

The company's three mills of 20, 43, and 90 stamps respectively are known as A, B, and C, and have cost, with improvements up to date, £145,343 17s. 9½d., as shown by the trial balance sheet. The cost varied from £1 16s. 7½d. in mill C, which crushed 42,153* wet tons, to £2 11s. 10d. in mill A, which crushed 9,934† wet tons.

The saving of silver amounted to 90·7 per cent.

The report of the Elkhorn Company, of Montana, for 1891, affords another excellent illustration of close saving and business-like management.

The mill, which crushed 11,645 tons (dry) during the 12 months ending December 31st, 1891, saved 93·78 per cent‡ of the silver contents of the ore at a cost of (9·226 dollars)§ £1 18s. 5½d., a close approximation to the figures just given.

TAILINGS MILLS.

Silver-mill-tailings are generally concentrated on concentrators, or on blankets, in sand-slucies, and either leached, or treated in pans on the Comstock system (using chemicals); which has given rise to what are known as tailings, or auxiliary mills.

Tailings from silver mills can in fact often be treated profitably by storing them in dams, leaving time, air, and chemical agency to effect their oxidation, and then treating them raw in pans, no drying or chloridizing being required.

The chief drawbacks against this method are the uncertainty as to the time necessary for complete oxidation of the minerals present, which may be taken from 2 to 4 years, and the necessity of constructing large storage dams.

* Representing 40,067 dry tons. † Representing 9,318 dry tons.

‡ In 1890, 86·83 per cent. was saved, the increase in 1891 is attributed to using extra salt. § For analysis, see Appendix.

Mr. Eiasler states* that, in some establishments of this kind in Nevada, the quantity of sulphate of copper supplied to the pans with this system of treatment varies from 3 to 6 lbs. per ton of tailings, while the salt amounts to 20 or 30 lbs. The pans are covered, and supplied with steam at a high temperature.

He places the yield at about 60 per cent., dealing with an ore worth £3 to £3 10s. per ton, and gives the current cost as follows :—

	£	s.	d.
Labour	0	6	0
Quicksilver lost	0	4	0
Salt	0	3	0
Sulphate of copper	0	2	6
Fuel	0	5	0
Castings	0	0	6
Total	£1	1	0

In Avery's tailings-mills in Washoe valley, where wood is £1 4s. per cord, the cost per ton is stated to have been 14s.

It is usual in Nevada for two sets of samples to be taken as a basis upon which to determine the value of the ore, when it is treated at customs establishments. One of these samples is taken from the waggon conveying the ore from the mine to the mill, the other from the mill after the ore has been crushed. The waggon sample is obtained by drawing from each waggonload of ore a sample of rock, and mixing the total number of samples of the loads sent to any one mill at the end of the day. This bulk sample is then quartered down, the mill being charged with the weight of ore, and the amount of gold and silver represented by assay. The mill sample, which is to serve as a check on the waggon sample, is taken by allowing the crushed ore as it comes from the battery to run into a pail, held at the end of the trough leading to the tanks.

A sample of this kind is taken in most mills every hour, in some every half-hour, and the accumulated samples are well mixed, dried, and reduced to a sufficient quantity for assay.

The pail or vessel in which the crushed ore is caught must not, of course, be allowed to overflow.

In some mills the samples are taken from the tanks after the sand has deposited itself in them, either from the surface or preferably with a tube sampler.

Strange as it may seem the waggon samples and mill samples generally differ in yield, and the former is usually the highest.

This was proved in the late celebrated suit tried before Judge Hebbard, Fox *versus* the Hale and Norcross Co. In practice, therefore, both assays are duly considered, and an adjustment arrived at.

* *The Metallurgy of Silver*, page 114.

A. D. Hodges, in an interesting paper on pan-amalgamation,* estimating on 46,500 tons of Comstock tailings treated at Drayton, Nevada, calculates the cost of treating them as follows :—

Preparing and hauling	...	...	...	s.	d.
Milling...	...	...	...	1	3½
General expenses	...	...	...	8	1½
				0	10½
Total per ton	...	...	...	10	3½

Some of the sand so treated seems to have run about 15s. 3½d. in silver, and 4s 8½d. in gold, total £1, and yielded in bullion 75·8 per cent. of the silver, and 25 per cent. of the gold, total 63·8 per cent., whilst some of the slimes averaged £2 15s. 3d. silver, and 9s. 5½d. gold, total £3 4s. 8½d., and yielded 85·8 per cent. of the silver, and 42·5 per cent. of the gold, total 79·5 per cent.

The loss of quicksilver, treating sands at Drayton, ran under ½ lb., and with slimes from ¾ to 1 lb. per ton.

The bullion from the treatment of the sands did not run over 150 fine, and with the richer slimes the best results were got when it was from 200 to 250 fine.

In Dakota, it may be mentioned that with free-milling gold ores, it cost 4d. for mill labour, to produce 4s. 2d. worth of gold.

In Nevada, on the other hand, though over five times as much work is required per ton treated, it costs only about 3½d., but this seeming contradiction is explained by the higher grade of the Nevada ores.

A 20 pan mill, without any special arrangement for catching mercury working on tailings, made a gain of 700 lbs. of mercury in 6 weeks, which was but a small part of the mercury actually contained in the slimes.

In view of these losses it generally pays to employ concentrators to work up the mill-tailings. Sometimes a machine, known as a Varney amalgamator, is set in the tailings-sluice.

As battery slimes require no grinding it would seem most advantageous to charge the quicksilver direct into the pan, but experience has shown that better results are obtained by charging the chemicals with the slimes and thoroughly mixing them for about two hours with the muller up, and then adding the mercury, as the slimes form a pasty mass which might hold and carry off the finely divided quicksilver. In treating such material one-half its bulk in sand (tailings from the pans), and sometimes more, is added to the charge.

In many so-called free-milling ores of silver, or silver and gold combined, there are small quantities of sulphides of the base metals, not

* *Trans. Am. Inst. Min. Eng.*, vol. xix., page 231.

sufficient in quantity or value to make the ore suitable for roasting, yet enough to prevent a high extraction by free-milling, besides increasing the cost. Such ores can be best treated by the combined process of concentration and amalgamation.

Stamping the ore wet, passing it over copper plates, concentrating in vanners, and then amalgamating the tailings by the continuous process, lessens or dispenses with grinding in the pans, decreasing the wear of castings and fuel consumption; decreases the losses of quicksilver; increases the capacity of the battery by permitting coarser crushing; raises the percentage of extraction, and gives higher grade bullion.

The Montana Company by adopting this process obtained, it is said, an increased saving over ordinary pan treatment of from £1 13s. 4d. to £2 1s. 8d., decreased the loss of mercury to $\frac{3}{4}$ lb. per ton of ore, and increased the tenure of the bullion from .500 to .900 fine. The cost of the process is from 12s. 6d. to £2 1s. 8d. per ton, and less water is required than with ordinary pan-amalgamation.

It is sometimes more expedient (depending on the base metals present, and the way the ore breaks) to crush finer in the battery and grind less, as before mentioned.

Since ore will break naturally where there is most mineral, by disengaging it as far as possible in crushing, as mercury has a greater affinity for the precious than for the base metals, there is less likelihood of its becoming foul and inactive through taking up lead and other things which grinding tends to make it do.

In Arizona the loss in melting bullion averaging .938 fine (from volatilization and skimmings) is stated by Mr. Egleston to be 7.55 per cent.

Ores, like some of those of the Comstock, that contain their gold and silver more or less free, will mill from 60 to 80 per cent. by the Washoe process and in exceptional cases, like those of White Pine (Nevada) and Silver Reef (Utah) to even 85 per cent. Roasting milling, on the other hand, gives an extraction of from 80 to 93 per cent., and in exceptional cases 94 per cent.

The combined process yields often 75 to 85 per cent.

THE PATIO PROCESS.

This very ancient and interesting process cannot be passed by without comment, as Mexico, which is its home, so to speak, is, it must be recollected, the second largest silver producer in the world, and it is safe to say that three-fourths to seven-eighths of the silver it returns is obtained by the patio process.

The practice at San Dimas (State of Durango) may be considered typical, and is excellently described by Mr. R. E. Chism,* whose paper contains detailed information on the subject. Englishmen and Americans alike have gone into Spanish America from time to time expecting to revolutionize this time-honoured system by introducing more modern metallurgical methods, but in most cases they would appear to have failed in doing so, leaving abandoned reduction works all over the country as monuments of their errors. If we look for an explanation, it is to be found in the neglect of local conditions on which the success or failure of every process more or less depends.

The patio, with its cheap plant and fairly close extraction in Mexico, where saving of time is a secondary consideration, where transportation is difficult, where the ores are rich, and where animal power, space, and labour are cheap, whilst fuel and other necessities are dear (Central America possessing a suitable climate, and labour accustomed to the work from time immemorial) can, in fact, hold its own for the treatment of ores, which do not contain more than a trace of lead and zinc, where other processes would fail.

The silver, which the patio yields, is almost free from impurities and baser metals. An assay of several bars showed an average fineness of 0.994 silver and 0.035 gold. Mr. Chism gives the cost of treatment in a large hacienda where the tahonas were in two groups, and were worked by gear connected with an over-shot waterwheel, where the breaking was done by wooden stamps shod with iron (also driven by a waterwheel), and where the washing was done by a water-power washer, working a trilla of 19 tons, as follows:—

				Cost per Ton of 2,000 lbs.		
				£	s.	d.
Breaking, grinding, and cost of tools	...	...	...	1	7	9
Amalgamator's wages	...	...	...	0	6	11
Scraping tahonas	...	...	...	0	0	8
Carrying and washing scrapings	...	...	...	0	0	5½
Concentrating tailings of scrapings	...	...	...	0	0	3½
Carrying slime from tahona to patio	...	...	...	0	1	9
Mules and keep	...	...	...	0	15	6
Labour, spreading trilla and mule driving	...	...	...	0	6	8
Labour, washing trilla	...	...	...	0	2	4
Charcoal, for retorting silver	...	...	...	0	1	11½
Concentrating tailings of trilla	...	...	...	0	8	7
Materials—				£	s.	d.
Salt, 600 lbs. at 4d.	...	...	...	10	0	0
Sulphate of copper, 125 lbs. at 1s. 0½d.	...	...	...	6	10	2½
Precipitated copper, 25 lbs. at 2s. 9d.	...	...	...	3	8	9
Quicksilver, 133 lbs. at 2s. 7½d.	...	...	...	17	6	4
Total cost				£5	12	1½

* *Trans. Am. Inst. Min. Eng.*, vol. xi, page 61.

The cost to the owners would probably not exceed £5 4s. 2d., as the above costs include a certain charge for profit.

At works where the tortas are of small size (about 10 tons) and the ore is broken without the aid of water-power, inclusive of superintendence and interest on plant, the cost is said to be £5 14s. 11d.

The concentrates obtained from the planilla-treatment and washing in the boliche are shipped and smelted in Germany.

From 70 to 75 per cent., and in some few cases perhaps 80 per cent., of the assay value of the ore in silver is saved by the patio process, 72 per cent. being probably about the average; whilst of the gold present 40 per cent. is lost, 20 per cent. of the remainder goes with the silver, and the rest is recovered from the tailings or is caught in the tahona.

The process from start to finish takes from 23 days to 7 weeks.

In *The Engineering and Mining Journal*, New York, of May 7th, 1892,* Mr. E. du B. Lukis describes, what he claims to be, a recent improvement on the patio system specially applicable to ores containing antimonial and arsenical sulphides of silver, together with ordinary sulphides and some chlorides.

The ore, instead of going direct to the patio after crushing, is first roasted for 10, 12, or 20 minutes. The object of this roasting is merely to give a quick start to the process, and while, owing to its rapidity, it is said not to entail a loss of over $1\frac{1}{2}$ to $2\frac{1}{2}$ per cent. of the silver by volatilization; comparative trials have, it is asserted, proved the benefit to be derived therefrom.

It is not desirable to roast sweet, but only to break up the molecular affinity of the particles of the mineral by heat, so as to hasten the progress of the after-chemical process with a view to save labour and time.

The most important part of the modification in treatment, however, lies in the use of hyposulphite of soda, for if roasted ore be treated by the ordinary patio method it will not work, the quicksilver gets hot at once, and nothing can be done with it.

It is also claimed that it is now possible to arrive at the quantity of sulphate of copper that will be required to beneficiate the cake from the start, reducing the treatment nearly to a certainty. To avoid the usual loss of quicksilver, the amalgamation is stopped before the difficulty of the patio treatment commences (when in fact the free silver ores have been amalgamated), the amalgam is then washed out in the usual way, and the more refractory silver minerals are concentrated. The results are stated to have been satisfactory, showing an extraction of 92 per cent. of the assay value.

* Page 496.

The ores taken for trial were of a mixed class. One-third of the silver being antimonial or ruby silver, the remainder mostly silver glance, but with pyritiferous silver ore and some chlorides. The assay value was 50 dollars per ton. The heavy minerals amounted to about 10 or 15 per cent. of the whole.

The ores were stamped dry to pass a 60 mesh screen, and roasted in an ordinary reverberatory furnace with a hearth measuring 8 feet by 6 feet. The temperature was raised to a good red heat. Charges of 400 lbs. were mixed with $2\frac{1}{2}$ per cent. of salt, spread over the hearth and kept gently stirred with a rabble. Eight minutes after charging, a sample was taken out and washed in the tentadura or assay horn to show the colour of the concentrates. It is by the colour that the calciner knows when to stop roasting. When sufficiently roasted, which does not in any case take more than 20 minutes, the charge is quickly withdrawn, and a fresh one introduced.

The hot ore is allowed to remain in a pile until next day, when it is spread on the patio, moistened with water, and trodden into a soft pulp, with an addition of $\frac{1}{2}$ per cent. of salt. This being done in the morning, sulphate of copper can be added three or four hours later. The required quantity can only be ascertained by experiment, but in the case cited $4\frac{3}{4}$ ounces per 25 lbs. were found the right quantity. After this addition the pulp is again trodden and left till next day.

Early next morning a guide is taken from the cake by a peon who walks across it in two diagonal lines taking small portions of the pulp here and there, and accumulating a sample as near as can be guessed of about 100 lbs. This is placed in a corner of the patio, and divided into four portions of 25 lbs. each, to each of which different quantities of sulphate of copper are added, say 1, 2, and 4 grammes (15, 30, and 60 grains) respectively. Assays of each are taken in turn (commencing with the pulp of the cake itself), and mixed up with a globule of mercury in the tentadura and washed, when the action of the sulphate on the mercury will be seen by its colour. It ought to remain bright and quick, and sulphate can be added in small quantities to the guide until the mercury shows a trace of heat, *i.e.*, becomes discoloured and leaden in tone, which indicates that a gramme (15 grains) too much per 25 lbs. has been added.

The amalgamator now knows that he may add 1, 3, or 5 grammes (15, 45, or 75 grains) as the case may be per 25 lbs. of cake. Done with care and patience, this should be a sure guide as to the total quantity of sulphate the cake can stand.

If the process were now continued, as with raw ores, the mercury would become very hot by next day, and soon not work at all, that is to say become dirty in appearance and cease to form silver amalgam. To avoid this trouble, hyposulphite of soda has been used and found to work successfully, whilst it helps to hasten the process. It must, however, be employed with great care, the quantity being found by trial for determined mixtures of ore, and upon this depends its success. Roughly speaking, $\frac{1}{2}$ ounce per 100 lbs. of pulp will be sufficient, more would destroy the mercury.

Having decided upon the additional quantity of sulphate of copper that can be added on this the second day, and having trodden it into the pulp thoroughly, the hyposulphite of soda may be added and trodden in the same way, and immediately afterwards the mercury should be sprinkled over the cake and trodden in, in such proportion as to take up by amalgamation two-thirds of the assay value, or 4 ounces of mercury per ounce of silver present.

The following or second day after incorporating the mercury, treading with horses, spading over, and taking assays will be all that is needed, unless it is found that a guide of 25 lbs. can stand an addition of sulphate of copper. This should not be necessary if the quantity be properly determined before adding the hyposulphite. More than half the mercury will be converted into amalgam by the evening.

The following or third day after incorporating, the same work is required, paying more attention to the assays, and if necessary adding more sulphate of copper, and by evening more than three-quarters of the mercury will be taken up.

The fourth day, the treading, etc., go on, and by evening the mercury should all be converted into silver amalgam, and should be bright and dry, and free from a straw-colour that indicates loss. The next morning the baño or bath is added, consisting of $1\frac{1}{2}$ ounces of mercury per ounce of silver in the cake, which collects the fine amalgam.

This has to be done quickly, and the washing of the pulp follows immediately. The amalgam is collected, pressed, retorted, and the bullion in due course melted down.

This treatment extracts that portion of the silver which cannot be concentrated, and it is found easy to concentrate the remainder on vanners, or other machines, obtaining, if necessary, two grades, the first assaying 1,500 ounces or over per ton, and the second 40 to 60 ounces. The waste is then too poor to treat further.

These trials were made with an average temperature of 70 degs. Fahr. in the shade.

The loss of mercury, including the consumido and mechanical loss is said to be about 18 ounces for every 16 ounces of silver, as compared with 22 to 24 ounces lost in the ordinary patio. The gold is collected, if present, partly in the amalgam and partly in the high-grade concentrates. The cost of working a ton of ore assaying 50 dollars is estimated at £1 5s. 10d., extracting 85 per cent. of the silver.

THE FONDO AND TINA PROCESSES.

In South America, the patio process seems to have been used up to about 1830, when, in consequence of the large quantities of negros or sulphide ores, which began to be found there, it was superseded by the fondo or calderon method, with variations known as the tina, Francke-tina, etc.* The original fondo process was invented, it is believed, in Chili, in the year 1609, by a priest, Alvaro Alonzo Barba,† and was used for rich surface-ores, chlorides, bromides, and oxides, which, if not rich enough, required to be concentrated in the planilla, but it was on the whole a very slow process.

The tina process in a modified form‡ is applicable to all ores of silver except argentiferous sulphides of copper, galena, or blende, and to ores which contain more than 1 per cent. of free arsenic, which causes great losses of mercury. The inventor is not known, but it has been in constant use about Copiapo since 1862.

Prof. Egleston§ says of it:—"The whole operation is very simple, quicker with much less loss than the barrel, more certain in its reactions than the patio, and is applicable to almost all the ores found in Chili. It is even cheaper under some circumstances than the lead-fusion."

The cost of treating a ton of £8 6s. 8d. ore, not including interest on sinking fund, working 8 tons a day, is about £1 8s. 7½d.

The process now used in Bolivia, a modification of the tina and fondo processes, seems to be an advance on the former methods, as it includes many of the best points of the tina and pan processes, and may be used for base as well as docile ores of a great variety of yield.

It is closely related to the Francke-tina method, which has been described by Mr. Edgar P. Rathbone|| and Mr. Arthur F. Wendt.¶

Mr. Wendt says of the Bolivian method, "That large losses of silver were experienced through volatilization when the ore was roasted with

* Egleston, *Metallurgy of Silver*, page 312.

† Percy, *Metallurgy of Gold and Silver*, part I., page 656.

‡ *Revue Universelle des Mines*, series 1, vol. xxxi., page 493.

§ *Metallurgy of Silver*, page 323.

|| *Proc. Inst. Mech. Eng.*, 1884, page 257.

¶ *Trans. Am. Inst. Min. Eng.*, vol. xix., page 74.

salt in revolving mechanical furnaces, and these could only be obviated by an oxidizing roasting in reverberatories (following lump roasting in kilns), adding the salt after complete oxidation has taken place."

The extraction remains practically the same, whether the chloridization of the ores is 20 or 90 per cent. This is so entirely different from the generally conceived notion of silver-milling in the United States that too much emphasis cannot be laid on this point.

All classes of ores can be worked by the process, not even excepting galena, although the extraction, with the latter and when blende is present, is of course reduced. The bullion obtained is generally 900 fine or over, alloyed principally with copper. Treating crude ore which carries 75 to 80 ozs. the tailings average about 10 ozs.

The use of bluestone in pan-amalgamation with the object of producing a sub-chloride of copper, which is an active agent in the pan process, has been commented upon before, but when an iron pan is used this sub-chloride is being constantly destroyed. When a copper or bronze vessel, however (like the tina), is used, the sub-chloride is, on the other hand, being constantly regenerated, and this is the essential difference between the two methods, although of course the same results can be obtained at the expense of extra bluestone in the pan in dealing with base ores.

The choice between the tina and the iron pan process must, therefore, Mr. Wendt thinks, depend on the relative price of sulphate of copper and iron-castings as compared with copper, to which must be added the extra refining charges, carriage, etc., on more or less coppery bullion.

The cost at the Real Ingenio Potosi is stated to be 90 Bolivians (£4 13s. 9d.) per cajon of 5,000 lbs., or about £1 17s. 6d. per ton, treating 8 tons per day, but this is, of course, no criterion of what could be done with cheaper freight and better labour in works of large capacity.

The process gives an extraction of 80 to 85 per cent. in Bolivia, and probably on rich chloride ores like those of Caracoles (worked by the Kroehnke process) it would yield returns running up to 92 to 96 per cent., as the extraction on roasted ores averages 90 per cent.

THE LEACHING OR LIXIVIATION PROCESS.

This process consists in first roasting the ore with salt to convert the silver into chloride, then dissolving the chloride of silver in a solution of hyposulphite of soda and precipitating it with sulphide of lime or soda (as a sulphide of silver) and refining this latter product. The Russel process is a modification of this, consisting in the use of what is known

An extra solution (prepared by adding a certain percentage of sulphate of Copper to the ordinary hyposulphite solution) after the ordinary solution has extracted all the silver it will take out.

Lower cost of plant and in some cases less expense in treatment are advantages which are claimed for leaching treatment, but against these must be set the difficulty of obtaining men with practical experience and chemical knowledge necessary to conduct the process, and the fact that the reactions involved are often obscure, and sudden disturbances in working, may be introduced by changes in the character of the ore.

Since lixiviation was introduced into Mexico by Mr. Ottokar Hofmann, in 1868, it has become extensively used, and has risen to a position of importance in some parts of America for the treatment of refractory silver ores. All silver ores are capable of being treated by it with a certain amount of success, except those which contain so much lead that they are classed as smelting ore, or which on account of a clayey-calcareous or talcose gangue, do not permit of free filtration. This latter objection can, however, be overcome, if other circumstances admit of it, by a previous slight concentration. The ore must first be pulverized to fit it for the process, and though this is purely a mechanical operation it does not follow that the machine which will crush the largest amount of ore at the least cost is necessarily the best to select. One has to consider as well in this connexion, the physical condition in which the ore leaves the machine, as on this depends to a great extent a most important part of the process—the roasting. Ores which contain a considerable amount of argentiferous galena or zinc-blende require to be pulverized very fine in order to ensure a satisfactory chlorination, while a coarser pyritic-pulp (whether consisting of iron or copper pyrites) will chloridize well. In selecting machinery for the purpose attention must therefore be paid (as in every other process) to the nature of the ore.

The choice of crushing machinery, for an ore requiring leaching, lies mainly between rolls and stamps. The former produce a much more uniform grain than the latter (the ore and gangue-particles being of more even size), which is of distinct advantage for concentration, but may be the exact opposite for roasting. The most suitable condition of the pulp for roasting in dealing with ore of the kind described, is, in fact, a mixture of fine ore-particles in a coarse gangue, a condition of pulp which is promoted by dry-crushing with stamps. This is explained by the fact that the ore, as a rule, having a higher specific gravity than the gangue cannot so readily escape comminution as the lighter particles of rock, and is only discharged from the screen when reduced to a condi-

tion of comparatively fine pulp, while the lighter gangue is expelled when much coarser.

Roasting.

In roasting, the ore undergoes a chemical decomposition, and this can frequently be better accomplished if the ore-particles are of fine size. The fine condition of the pulp does not seriously interfere with the subsequent lixiviation, because most ore after a chloridizing-roasting (chlorination) becomes sandy, and will filter freely if the gangue is not of a clayey nature. In order to convert the silver into chloride, as before mentioned, the ore must be roasted with salt; and to roast successfully, a sufficient percentage of sulphides must be present, as they produce by their decomposition sulphuric acid (which acts on the salt and liberates the chlorine necessary for the formation of silver chloride). The base metals in the ore are converted into oxides, chlorides, and sulphates. The requisite amount of salt (depending on the character of the ore) varies from 4 to 10 per cent. The salt is either added to the ore before it enters the furnace, or after it has reached a certain stage of oxidizing-roasting. The selection of the proper roasting-furnace to employ is a matter of great importance: this was proved by Mr. Hofmann in Mexico, in experiments made on the San Francisco del Oro ore, in 1888.

It is to be remarked in favour of the Stetefeldt roasting furnace that it requires less salt than any other for chloridizing-roasting silver ores: the decomposition of the salt is very perfect, the chlorine and chloridizing gases emanating from the roasted ore at the bottom of the shaft, acting on the falling ore. Ores which are free from lime and magnesia, can be chloridized in this furnace with a minimum of salt, and it seems to be specially adapted to roasting ores containing copper. Mr. Aaron states that at the Surprise Valley mill, California, an average chlorination of 92 to 93 per cent. was obtained during a nine months' run, roasting silver ores of £15 12s. 6d. assay value, with only $2\frac{1}{2}$ to 3 per cent. of salt. Generally, 5 to 8 per cent. of salt is required in the Stetefeldt furnace, if the ore carries lime and magnesia or a larger percentage of base sulphides. The chlorination varies with the character of the ore, and the attention with which the furnace is managed; results as high as 97 per cent. have been obtained, while they generally range from 87 to 93 per cent. Ores free from sulphur, or with only a slight percentage, should be mixed with 1 or 2 per cent. of iron pyrites, otherwise the salt cannot be decomposed. Oxidized ores carrying peroxides of manganese and iron, which give off oxygen, can be successfully chloridized by themselves. The best results are obtained by mixing oxidized with sulphide ores, more parti-

cularly if the former contain peroxide of manganese. The presence of copper is very favourable for the chlorination of the silver, and if the ore is of such a character that it will bear a high heat without sintering, the chloride of copper formed in the upper part of the shaft can be almost entirely decomposed, and very fine bullion produced by amalgamation. At the Surprise Valley mill, for example, the ore roasted at a low temperature gave bullion only 300 to 400 fine by amalgamation, the base metal being copper. By roasting at a high temperature the bullion was almost freed from copper, its average fineness being 980, running for nine months. All antimonial ores are chloridized with great facility, and with a good system of dust-chambers, the loss of silver by roasting is hardly perceptible. The same is the case with zinc-blende. In roasting ores entirely free from, or with a small percentage of, sulphides, the want of sulphuric acid must, as before remarked, be remedied by adding another substance. A cheap substitute for pyrites is found in green vitriol (sulphate of iron) of which $1\frac{1}{2}$ to 3 per cent. is added when 8 to 10 per cent. of salt is used. The copper is first calcined to drive off its water of crystallization by a gentle heat, and the above percentage of the calcined material is taken. The sulphate then acts on the salt as if it were created in roasting; copperas may also be added to arsenical ores free from sulphurets. If there is a great deal of lime in the ore, it takes up sulphuric acid, forming sulphate of lime, which remains undecomposed; ores containing lime require, therefore, a larger proportion of copperas or iron pyrites, sufficient to transform all the lime into sulphate. At the same time, lime assists in decomposing the base metal chlorides in roasting (5 to 6 per cent. being sometimes added to base ores in a pulverized condition), whilst it does not attack the silver chloride; but too much must not be added if the ore is to be amalgamated afterwards. The lime should be added towards the end of the roasting, introducing 2 per cent. to commence with, and well mixing it with the ore.

Usually, ores containing not more than 8 per cent. of sulphur roast well in the Stetefeldt furnace, but in operating on the San Francisco del Oro ore the results turned out unsatisfactory. This ore contained 25.5 per cent. of zinc, 11.56 per cent. of lead, and 21 per cent. of sulphur, and proved too refractory for the Stetefeldt process. The ore (when sifted into the furnace) created by the sudden combustion of the sulphides an extremely high temperature in the upper portion of the shaft, which caused the suspended ore-particles to slag to globules (a coating of silicates being formed immediately around them), which prevented their further oxidation and chlorination. An analysis showed that 8.48 per cent. of the sulphur, in

fact, remained unoxidized. It was found also that a separation of the ore took place in the furnace, the shaft receiving the portion carrying most of the lead, while the lighter portion, containing most of the iron pyrites, was carried over into the descending-flue, where, owing to this circumstance, combined with the high temperature, that particular portion of it was better chloridized than the bulk which passed through the shaft. An excess of salt lowered the chlorination, and 12 per cent. was found to give the best results (60·8 per cent. chlorination) in the descending-flue. Another bad feature was the formation of lumps and crusts in the upper region of the shaft, and choked the lower side of the feeding-screen.

An ore of the class operated upon requires to be submitted to a long and gradually increasing temperature before the salt is added ; and as the principle of the Stetefeldt furnace is just the reverse of this, the results could not but be unsatisfactory. Heavily sulphide ores, especially if they carry zinc, require more draught in roasting than lighter sulphide ores ; and this is particularly the case when they are exposed for such a short time, as in the Stetefeldt furnace, to the action of air and heat. Mr. Hofmann's experiments in roasting the ore of the San Francisco del Oro mine in a Stetefeldt furnace go to show :—

1. An incomplete oxidation of the sulphide minerals, the main portion of the ore still containing 8·48 per cent. unoxidized sulphur when roasted with salt, and 7·6 per cent. when roasted without salt.
2. An insufficient chlorination of the silver. The highest chlorination of the ore in the shaft was only 16·9 per cent., and as 62·5 per cent. of the whole volume dropped into the shaft, the somewhat higher results obtained in the descending-flue could not much improve the average.
3. That the principle of the Stetefeldt furnace is contrary to the conditions, the maintenance of which are so essential to roasting ores containing much zinc blende and galena.
4. That, on account of the sudden exposure of the raw ore-particles to such a high temperature, they melt to minute globules, which make the ore unfit for further treatment.
5. That a concentration of the lead minerals takes place in the shaft, which is disadvantageous.
6. That about 25 per cent. of the ore, when passing through the furnace, is changed into hard lumps of almost raw ore.
7. That the lower side of the feed-screen becomes rapidly encrusted and the holes obstructed, requiring frequent changes of screens.

The ore after passing through the shaft of the furnace had a dark, almost black colour, and continued to emit volumes of sulphurous acid gas when discharged, and for some days after, but no chlorine. Mr. Hofmann next tried re-roasting the partly roasted ore from the Stetefeldt in a modified Howell furnace. Having previously ascertained that this ore contained only 1·3 per cent. of salt, 6 to 8 per cent. more was added, and the feed regulated so as to put through from 5 to 9 tons per 24 hours. The average of thirty-three charges worked thus gave :—average of re-roasted ore, 31·42 ounces of silver per ton; average of leach-tailings, 17·55 ounces per ton; average of chlorination, 44·2 per cent.

It is a point to note that the consumption of wood in re-roasting proved to be much greater than in roasting raw ore. This is accounted for by the main portion of the sulphur, combined with the pyrites, having been burnt off in the Stetefeldt furnace. During the second roasting, the furnace was deprived of the heat of combustion derived from this source, so that additional extraneous artificial heat had to be furnished. To re-roast in this manner 8·3 tons, it took 26 cargas of wood (12 cargas = 1 cord), while it took only 16 cargas to roast 10 to 11 tons of raw ore. The roasting capacity of the furnace was also diminished. By dumping the red-hot ore from the Stetefeldt direct into a reverberatory hearth, the extra consumption of wood during the finishing roasting could doubtless have been materially lessened; but what made this plan impracticable was the change the ore underwent in passing through the Stetefeldt furnace, which interfered with attempts to obtain a high chlorination result afterwards.

The re-roasted ore was of a red-brown colour, smelled of chlorine and did not emit any sulphurous acid gas, but it still consisted principally of the little globules, of which mention has been made, quite a large number of which remained black, no matter how long the ore was kept in the furnace. Some were magnetic, but the majority were not. Between the fingers, the re-roasted pulp felt sharp, like powdered glass. The temperature was kept at a proper degree, and there was an abundant draught, the dust-chambers and furnace having been previously cleared. Still it was impossible to obtain more than 44·2 per cent. of chlorination, owing undoubtedly to the silicates formed during the roasting in the Stetefeldt furnace. A jet of steam* introduced into the reverberatory hearth attached to the modified Howell furnace considerably improved the results, but still did not give sufficient satisfaction.

* The introduction of steam through the bridge of the furnace generally increases the fuel consumption.

The average of thirteen charges showed:—average of re-roasted ore, 31·0 ounces per ton; average of leach-tailings, 10·37 ounces per ton; average of chlorination, 66·6 per cent. The ore still contained a considerable number of globules, but they had changed their colour to red-brown, and between the fingers the ore felt soft and not so sharp and glassy as when roasted without steam. The Howell furnace alluded to above was not a regular Howell, but consisted of a revolving cylinder of uniform diameter with a shell of boiler-plate lined with bricks throughout its length (the principle on which it works is identical, however, with the Howell furnace), and had a reverberatory hearth in front, attached at the end.

The Howell, like the Stetefeldt furnace, requires the salt to be mixed with the ore before entering the furnace. With some ores this is immaterial, but it is a matter of the greatest importance for the del Oro ore. If the salt is previously added the ore becomes sticky, encrusts the furnace rapidly, and leaves the furnace mostly in lumps imperfectly chloridized. If the ore is charged without salt it remains dry and sandy, but a very annoying separation takes place. The fine particles are carried by the draught into the dust chambers, and only the coarse sand passes through the furnace without being sufficiently desulphidized. If, then, salt be added in the drop-pit, only a small percentage of silver becomes chloridized. The best results gave only 29 per cent. of chlorination. In order to diminish the separation, 2 per cent. of salt was added to the ore in the battery. This small percentage of salt made the ore sticky enough to diminish considerably the dusting, without causing the formation of lumps or too heavy encrustations.

By this method, the chlorination improved considerably, the average of three days' run being 67 per cent., but Mr. Hofmann convinced himself notwithstanding, that the Howell furnace, as such, could not roast the del Oro ore. The results were not sufficiently uniform and reliable; and though the roasted ore was left in a good condition, the average could not be brought above 67 per cent. An alteration being apparently required, which would give the ore more roasting time and allow of a better regulation of the temperature, Mr. Hofmann made the following changes. In front of the furnace, he constructed a shallow drop-pit and a fireplace, and on one side of the drop-pit, communicating with it, he built a small reverberatory hearth, 6 feet by 8 feet, the bottom of both being on the same level.

The reverberatory hearth contained one working-door and a 24 inches fireplace. When enough ore had accumulated in the pit to make a charge for the reverberatory hearth, it was pushed in with a hoe, each charge consisting of about 1,400 lbs. When starting the furnace, a strong fire

was kept up in both fireplaces, but after the process was in operation the fire in front of the cylinder was much lowered ; in fact so much so, that half the grate bars remained bare of wood. Only now and then a thin stick of wood was added, just enough to prevent the drop-pit getting chilled. Two per cent. of salt was added to the ore in the battery.

If the roasting be properly conducted, the blue flame of the ignited pyrites can be observed in the back part of the cylinder. Next to it, and reaching beyond the middle of the cylinder, the ore assumes a higher temperature, forming a belt of bright red heat. The part of the furnace next the fire (nearly one-third of the whole length) should look dark. The furnace is mostly heated by the combustion of the sulphides, and receives but little supply from the fireplace and reverberatory hearth ; in fact the ore in the cylinder should be left as much as possible to roast in its own heat. This is a very important condition to maintain, the object being to convert as much as possible of the galena and zinc-blende into sulphates and oxides before generating chlorine, and to avoid until then as much as possible the decomposition of the iron-salts. This can only be done by maintaining a low heat after the combustion of the pyrites.

An excess of heat is invariably connected with an excessive loss of silver by volatilization and by a low chlorination. Galena and zinc-blende roast quicker and better in a low than a high temperature. When the ore leaves the cylinder and drops into the pit, it should be of a dull red heat, while the colour after cooling should be dark yellow-brown. If the temperature be so kept, neither the odour of chlorine nor much of sulphurous acid can be detected. At an increased heat, sulphurous acid is again evolved strongly, showing that the oxidation is not yet completed. As the temperature in the cylinder is mostly produced by the combustion of the sulphides, the chief means of regulating the same is the feed. If too much ore enters the furnace, the belt of bright red heat increases, advancing more and more towards the front, and finally the whole furnace assumes this temperature. The ore dropping into the pit is very hot, emits heavy fumes and overheats the pit. If it be then removed into the reverberatory hearth, it takes a very long time to finish, necessitating an interruption in the feed of the cylinder.

On the other hand, if insufficient ore be charged, the belt of bright red heat gets smaller and moves towards the back end of the furnace. When the properly-prepared ore enters the reverberatory hearth, the salt is added and the temperature increased. It commences to fume, and swells without forming more lumps than an ordinary ore. In the beginning, strong fumes of sulphurous acid are emitted, but soon cease and chlorine appears.

The charge is finished if the fumes assume a mild and sweetish smell of chlorine; as long as they smell strong, roasting must be continued.

Mr. Hofmann made a series of experiments to ascertain the smallest amount of salt practicable, and found that 4, 6, 8, and 10 per cent. gave about equal results; 12 per cent. commenced to make the ore too sticky and produces less chlorination; 3 per cent. was sufficient if the roasting were very carefully conducted, but then only 1 per cent. had to be added in the battery and 2 per cent. in the furnace; 4 per cent., however, was safer, for then the result did not depend so much on the skill and goodwill of the labourers. The roasting capacity of the furnace proved much less for the del Oro than for ordinary ore. The cylinder was only 24 feet long, which could not roast more than $8\frac{1}{2}$ tons per 24 hours; but even with a 32 feet cylinder, Mr. Hofmann states he did not expect to roast more than 12 tons per day.

Each charge had to remain 2 hours on the reverberatory hearth. Though the ore was roasted in the reverberatory hearth at a somewhat increased heat, it could not be raised beyond dull red without losing too much silver by volatilization.

If the silver-bearing minerals of an ore be not of great density and decrepitate in the heat, the ore can be crushed coarse without endangering the subsequent roasting, but if the principal silver-bearing mineral, like the zinc-blende in the del Oro ore, be of great density and does not decrepitate, it is of the greatest importance to crush fine.

A series of experiments was made by Mr. Hofmann with ore crushed through No. 20 and No. 40 screens. He found that the ore crushed through No. 20, required a much longer time and was 27 per cent. less chloridized than the ore crushed through No. 40 screen. The material which passes through a battery-screen of a certain number, is much finer than the size of the meshes. Heavy ore makes a much finer pulp through the same screen than lighter ore. The pulp of the del Oro ore obtained by crushing through battery-screens Nos. 20 and 40, when sieved through sieves of different fineness, showed the following results:—

Battery Pulp when Sifted through Sieve. No.		Crushed through Battery Screen No. 20. Percent- age of Material passing through the Sieve.		Crushed through Battery Screen No. 40. Percent- age of Material passing through the Sieve.		Crushed through Battery Screen No. 20. Percent- age of Material remaining on the Sieve.		Crushed through Battery Screen No. 40. Percent- age of Material remaining on the Sieve.
30	...	93.8	...	100	...	6.2	...	0.0
40	...	87.3	...	100	...	12.7	...	0.0
60	...	78.8	...	98.95	...	21.2	...	1.05
80	...	71.2	...	93.80	...	28.7	...	6.20
90	...	67.1	...	90.50	...	32.9	...	9.50

These figures show how exceedingly fine a heavy ore is crushed (dry) in a battery, even through a screen with comparatively coarse meshes. Though 67.1 per cent. of the material crushed through screen No. 20 was finer than sieve No. 90, the average chlorination of quite a number of comparative roastings was 27 per cent. less than that of ore crushed through a No. 40 screen. This indicates how essential it is to crush such ores fine.

Mr. Hofmann found that in order to chloridize the del Oro ore well, it had to be crushed through a No. 40 battery-screen, which furnished a pulp of which only $9\frac{1}{2}$ per cent. was coarser than sieve No. 90. To produce such a fine pulp with rolls, would require such exceedingly fine screens that their use would be here impracticable. The crushing capacity of the battery was not much diminished by using No. 40 screen instead of No. 20, principally because the ore was so heavy.

For comparison, Mr. Hofmann ran 5 stamps, 12 hours, crushing through No. 20, and 5 stamps through No. 40, and found :—

No.	Lbs. of Pulp.
20 with salt furnished... ..	8,100
40 with 4 per cent. salt furnished ...	7,488
Difference in favour of No. 20 screen	612 lbs., or $7\frac{1}{2}$ per cent.

A very small reduction, if the great advantage gained for roasting is considered. Some ores gain much in chlorination of the silver, if left hot in a pile for several hours; this is mostly the case when an ore is insufficiently roasted, or when the nature of an ore is such as to require long roasting at low heat.

Additional chlorination can be produced by moistening the ore and leaving it for several hours in the pile; this is usually the case if the ore contains copper. Roasted ore containing caustic lime should not be left moist on the cooling-floor, hence the del Oro ore could not be wetted on the cooling-floor without decomposing some of the silver chloride. Mr. Hofmann remarks that the most important additional chlorination takes place, however, during base-metal leaching.

In the Silver King ore, Arizona, this additional chlorination amounted to nearly 6 per cent. Mr. Hofmann therefore filled the vat before charging about one-third with water and dumped the ore hot into it, thus producing a hot base-metal solution, and made the observation that by it not only the decomposition of the silver chloride was avoided, but that a considerable increase in the silver chlorination took place, amounting in some instances to 12.9 per cent. If the original chlorination was 75 per cent. or more the increase was, however, much less. By adding some cupric chloride to the water in the vat before dumping in the ore, badly roasted

charges gained as much as 34 to 38 per cent. (see charges, Nos. 9, 15, and 16 in annexed table). These are very important observations, and give the operator a means of correcting badly roasted charges.

The following table is a careful record of the results obtained in roasting the San Francisco del Oro ore in the Howell furnace modified by Mr. Hofmann, representing a two weeks' run. As each tank-charge contained the whole ore of 24 hours' roasting it offered a good opportunity of following each charge through the process from the condition of raw ore to tailings, and of ascertaining for each the loss by volatilization, etc.

Taking the average of the results we find the silver chlorination when the ore left the furnace was 68.4 per cent.; the additional chlorination was 13.3 per cent.; or a total of 81.7 per cent. The low average chlorination of the ore when leaving the furnace, was caused by the three badly-roasted charges 9, 15, and 16. The other eleven charges gave an average of about 75 per cent.

Mr. Hofmann remarks—"The total or actual chlorination of 81.7 per cent. may seem to be low, but if we consider that the ore is of low grade, averaging only 28.85 ounces per ton, and that 1 per cent. represents only 0.28 ounce of silver, and also consider that the ore contains about 37 per cent. of zinc-blende, and 13 to 19½ per cent. of galena, which carry all the silver, and that the ore was pronounced as being too refractory for chloridizing-roasting, we have to count the work done by the modified Howell furnace, as very satisfactory."

In order to ascertain the loss of silver by volatilization we have first to ascertain the loss in weight which the ore sustains during roasting. This can be done by the muffle test described by Mr. Hofmann in *The Engineering and Mining Journal*, New York, of April 23rd, 1887.* "Ten grammes of the raw pulp containing salt are placed in a roasting dish and roasted in the muffle for half an hour or an hour, then the sample is removed from the muffle, allowed to cool, weighed, placed back in the muffle, and roasted again for half an hour, then weighed again. This is repeated till two weighings are alike, or till in the last half hour of roasting, the ore does not lose more than 2 or 3 milligrammes. The difference between the original weight and that of the last weight expressed in percentage gives the highest possible loss which the raw ore can sustain."

Ten grammes of a sample of roasted ore corresponding with the sample of raw pulp are placed in a roasting dish, and also roasted in the muffle until two weighings agree or differ after half an hour's additional roasting not more than 2 or 3 milligrammes. The difference between the first weighing and the last (expressed in percentage) gives the weight which the

* Page 293.

WORKING RESULTS OBTAINED IN ROASTING.—EXPERIMENTS WITH THE MODIFIED HOWELL FURNACE.

Date, 1888.	Per Cent. of Salt used.	Value of Raw Ore.	Value of Raw Ore containing Salt.	No. of Tank-charge.	Value of Roasted Ore.	Value after Leaching in the Laboratory.	Per Cent. of Chlorination, when the Ore left the Furnace.	Value of the Vat-tailings.	Per Cent. of Actual Chlorination, Value of the Vat-tailings.	Loss in Weight which the Ore Sustained during Roasting.	Loss of Silver by Volatilization.	Loss of Silver by Tailings.	Per Cent. of Chlorination Gained in the Vat.	Number of Ores of Silver Extracted.	Per Cent. of Actual Silver Extraction.	Remarks.
		Ozs. per Ton.	Ozs. per Ton.		Ozs. per Ton.	Ozs. per Ton.	Per Cent.	Ozs. per Ton.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Ton.	Per Cent.	
April 20	5½	34.21	32.33	9	31.34	11.66	37.2	7.75	75.3	2½	5.2	24.5	38.1	24.04	70.3*	Assorted ore.
" 21	6	34.50	32.43	10	30.91	9.04	71.8	7.26	76.6	2½	7.1	21.8	4.8	24.52	71.1	
" 23	5	35.09	33.34	11	31.49	8.89	71.8	4.33	84.7	2½	7.8	14.1	12.9	27.40	78.1	
" 24	5	33.76	32.07	12	29.74	8.16	72.6	3.29	89.0	2½	9.5	10.0	16.4	27.17	80.5	
" 25	5	31.67	30.09	13	29.59	6.99	76.4	3.57	88.0	2½	4.1	11.5	11.6	26.72	84.4	Ore slightly assorted.
" 26	5	29.09	28.64	14	29.16	7.58	74.0	4.25	85.5	3½	1.7	14.3	11.5	24.55	84.4	
" 27	4½	27.35	26.02	15	25.95	13.27	51.9	4.25	84.7	3½	3.7	15.7	32.8	22.04	80.6*	
" 28	4	28.32	27.19	16	24.49	12.89	47.4	4.48	81.8	3½	13.0	15.8	34.4	20.16	71.2*	
" 29	4	26.02	24.98	17	22.16	4.95	77.7	4.76	78.7	3½	14.2	19.0	1.0	17.38	66.8	Unassorted ore, just as it was broken-down in the mine.
" 30	5	25.43	24.42	18	22.74	5.24	77.0	4.48	80.3	3½	10.1	18.3	3.3	18.20	71.6	
May 1	5	24.37	23.15	19	21.57	4.66	78.4	4.84	77.6	3½	10.0	20.0	0.8	17.05	70.0	
" 2	5	23.94	21.97	20	22.45	5.39	76.0	3.87	82.8	3½	1.3	17.0	6.8	19.46	81.3	
" 3	4	24.28	23.31	21	22.01	5.83	73.6	4.84	78.1	3½	8.7	20.0	4.5	17.31	71.3	Averages.
" 4	4	26.02	24.98	22	21.87	6.12	72.1	4.30	80.4	—	15.5	16.6	8.3	17.66	67.9	
	4.7	28.85	27.44		26.10	7.90	68.4	4.76	81.6	3	7.9	17.0	13.3	21.69	74.9	

Charges marked * were treated during base-metal leaching with cupric chloride.

roasted ore is still capable of losing if subjected to prolonged roasting. If we deduct this last loss from the highest possible loss, we obtain in percentage the loss in weight by volatilization which the ore has suffered during roasting in the furnace.

Owing to a great part of the lead and zinc sulphides being converted into sulphate, the San Francisco del Oro ores lose but a small percentage of their weight during roasting. The tests showed a loss of $2\frac{1}{2}$ to $3\frac{1}{2}$ per cent. With these figures and the assay value of the raw and roasted ore, the loss of silver by volatilization was calculated. The extremes were 1·7 and 15·5 per cent., and the table illustrates how variable this loss is. Mr. Hofmann says he found the del Oro ore more sensitively disposed for such losses than many others, even antimonial ores. The least increase of temperature above dull red causes a heavy loss, even if this increase of temperature lasts only for a very short time. Two or three thin sticks of wood thrown on the fire before they are needed may materially increase the loss. The loss by volatilization is not in direct proportion to the percentage of chloridized silver. In proof of this Mr. Hofmann instances the results of roasting Las Yedras ore at high and low temperatures in Brückner furnaces :—

High temperature, averages of 31 consecutive working-days, January 13th to February 12th, 1887.

	Furnace No. 3. Per Cent.	Furnace No. 4. Per Cent.	Average of both Furnaces. Per Cent.
Chlorination	71·3	74·2	72·7
Loss by volatilization ...	18·3	17·6	17·9

Low temperature, averages of 30 consecutive days, June 1st to July 1st, 1887.

	Furnace No. 3. Per Cent.	Furnace No. 4. Per Cent.	Average of both Furnaces. Per Cent.
Chlorination	81·7	81·3	81·5
Loss by volatilization ...	1·7	0·7	1·2

By comparing these average results we find an increase of	Per Cent.
chlorination, in favour of low heat, of	8·8
A decrease of loss by volatilization caused by low heat	16·7
Total increase of production	25·5

The roasted ore contained only a small percentage of lumps, not hard, but porous, which fall to powder if kept in contact with water for some time. If the ore be left dry in a pile, it hardens. If left undisturbed for a week or two, it becomes so hard that a pick is necessary to loosen it. In water, however, it softens easily again. The colour is usually red-brown,

but occasionally, if the ore contain less iron pyrites, it is yellow-brown. The heavy metals in the Yedras ore are principally converted into sulphates, and only a small proportion are present as chlorides.

The following is an analysis of the unassorted ore after roasting with 5 per cent. of salt :—Gold, traces ; silver, 0·09 per cent. ; lead, 9·00 per cent. ; iron, 6·00 per cent. ; zinc, 22·45 per cent. ; caustic lime, 5·65 per cent. ; antimony, 0·75 per cent. ; copper, 0·60 per cent. ; cadmium, 0·10 per cent. ; alumina, 3·09 per cent. ; caustic soda, 3·79 per cent. ; sulphuric acid, 13·16 per cent. ; chlorine, 0·88 per cent. ; soluble silica, 8·00 per cent. ; and insoluble gangue, 18·61 per cent.

Mr. Hofmann mentions an easy method of removing crusts from continuous discharging-furnaces, which can be done while the furnace is in operation. In the masonry at the back an opening is made, so located that with a long iron spade the interior of the cylinder can be reached just below the feed-pipe. Through this opening, 1½ dozen firebricks are introduced while the cylinder is revolving, and in moving slowly forward shove off the crust clean down to the lining. The crust when hot is soft and yields to the weight of the moving bricks. It is not necessary to interrupt the feeding. If bricks should be found too light, heavier, but not too large, pieces of castings may answer.

Owing to the large quantity of sulphides in the ore and the very low temperature at which the del Oro has to be roasted, the consumption of wood is very small. After the furnace is heated and the cylinder encrusted, it takes hardly any fire in front of the cylinder to maintain the proper temperature. In the reverberatory a little more fire is needed, but much less than with ordinary ores. Mr. Hofmann states that he weighed the wood during a couple of weeks, and found the total consumption during this period to be 220 cargas (at 300 lbs.). With this quantity of wood he roasted 115·8 tons, and therefore used 1·8 cargas per ton. 12 cargas of Parral wood being equal to 1 cord; if we express the consumption in cords, we find that with 1 cord of wood the furnace roasted 6·3 tons of ore. The cost of roasting in the modified Howell furnace (roasting 8½ tons per 24 hours) is as follows :—

	Dollars.
2 head roasters at \$1·50	3·00
4 helpers at 90 cents	3·60
4 per cent. salt, 680 lbs. at 1·27 cents ...	5·08
15·7 cargas wood at 75 cents	11·77
Steam-power, 10 cargas of wood at 75 cents	7·50
Oil, light, tools, etc.	2·00
Management, office, mechanic, assay office	1·78
Total	38·28

And the cost per ton, \$4·50, Mexican currency.

To ascertain the cost of steam-power a separate boiler was used for the furnace. It is evident that by using a boiler for only one small furnace, the expense per ton of ore will be much greater than if with the same boiler and engine several large furnaces are operated, but this was the only way of getting an estimate.

The steam for working the pump and preparing the calcium sulphide were supplied by the same boiler and had to be charged to roasting. It is included in the above statement, and will therefore not appear in the statement of cost of lixiviation.

As the statement of cost is made for only $8\frac{1}{2}$ tons per day, it would be misleading if the whole expense for management, mechanics, assay office, etc., were charged to the $8\frac{1}{2}$ tons, as these expenses would remain the same for 100 tons a day—the intended capacity of the new mill. The proportion chargeable on $8\frac{1}{2}$ tons, treating 100 tons per day, has therefore been debited to this item, but as there are three departments in the mill, viz., stamping, roasting, and leaching, each department has to be charged with one-third of this expense; 1.78 dollars represent therefore one-third of the cost.

The figures contained in the preceding table are the results of experiments obtained with different treatment as regards salt, temperature, time, etc., and the averages do not therefore represent the best obtainable results. This is especially the case in regard to loss by volatilization, which should be reduced as the men gain experience in handling the furnaces. They were good enough, however, to secure a profitable reduction of the ore, and may be accepted as a basis for calculations and estimates.

In order to increase the roasting capacity to the stamping power of the mill and for the sake of further experiments, Mr. Hofmann erected four double-hearth reverberatory furnaces (the lower hearth of 220 square feet surface, and the upper of 210 square feet surface) to supplement the modified Howell furnace.

Each double furnace took four charges of 1 ton each; when one charge was finished, all the others were moved forward, and on the first hearth a new charge dropped through the opening in the arch. From the second hearth the charge was dropped on the lower hearth, through an opening in the bottom near the working-door. The upper hearth was exclusively used for oxidizing-roasting, and 4 per cent. of salt was added while the charge was dropped on to the lower hearth. Every $2\frac{1}{2}$ to 3 hours a charge was done, and therefore each double furnace roasted from 8 to 10 tons per day, according to the quantity of lead the ore contained. The chlorination results were so near those obtained in the modified Howell

furnace that it is not necessary to give details, but Mr. Hofmann records the observations he made on a charge submitted to a prolonged oxidizing-roasting. They are too long to be given here, but will be found fully described in *The Engineering and Mining Journal*, New York, of February 23rd, 1889.*

He found that the ore during oxidizing-roasting sustained a loss of silver by volatilization of not less than 13 per cent. (not taking into calculation the loss in weight), and that this loss principally occurred during the seventh hour, at the time the ore assumed a dark red-brown colour.

Only a part of the soluble silver, he concludes, was present as sulphate, viz., 25·2 per cent. Of the 58·8 per cent. which was soluble, 33·6 per cent. was some other silver salt, not soluble in water, but soluble in sodium hyposulphite, probably silver antimoniate.

The reverberatory furnaces were built in pairs, two being connected with one main flue.

During four weeks the wood consumed by one pair of these furnaces was weighed. In this time 507 tons of ore were roasted at a consumption of 672 cargas of wood, or 1·3 cargas per ton. If expressed in cords, we find that one cord of wood roasted 9 tons of ore, an extremely small consumption.

The cost of roasting in the reverberatory furnace, for two double-hearth furnaces roasting 18 tons per day, was as follows :—

	Dollars.
2 head roasters at \$1·50	3·00
16 roasters at \$1·00	16·00
2 wood carriers and ore wheelers at 90 cents	1·80
2 carmen for raw ore chargers at 90 cents	1·80
23·4 cargas of wood at 75 cents	17·55
4 per cent. salt, 1,440 lbs. at \$1·27 ...	18·28
Tools, etc.	4·00
Management, office, mechanics, assays ...	3·77
Total	66·20

And the cost per ton, 67 cents, Mexican currency.

To form an opinion as to which roasting-furnace is the most suitable for an ore like the San Francisco del Oro, we have to take into consideration only the modified Howell and the reverberatory furnaces. The Stetefeldt furnace did not answer, and the Brückner furnace was not tried, as experience has shown that a large Brückner furnace could not roast more than 5 or 6 tons of such a heavy ore. Both the modified

* Page 190.

Howell and the reverberatory furnace gave about the same results, and the loss by volatilization was also nearly the same. The cost, however, was different, viz., 4.50 dollars per ton in the former, and 3.67 dollars in the latter, being a difference in favour of the reverberatory furnace of 83 cents per ton.

This ought to decide; still there are, besides the merits of the furnace, other circumstances to be taken into consideration. The reverberatory furnace requires quite a number of skilled hands, and the result depends much more on the skill and goodwill of the men, than with the modified Howell. Mexicans are, as a rule, if properly handled, very good workmen, notwithstanding that they receive such moderate wages, but they like to lay off on Sundays and feast days. On such days quite a number of inexperienced substitutes will be found working at the furnaces, and the roastings consequently suffer. The main trouble, however, occurs every year in spring and autumn, the time of planting and harvesting corn, when many leave the camp, and the mill is left short of hands. For this reason it may be more advisable in a large mill to use the modified Howell furnace, notwithstanding that the reverberatory furnace works cheaper and creates much less flue-dust. The Howell furnace forms a great deal of flue-dust, which is far from being roasted even if the furnace be provided with an auxiliary fireplace, as in the Howell-White furnace.

LIXIVIATION.

Base-metal Leaching.—The roasted ore is moistened with water and charged into wooden vats, in charges of 10 to 15 tons, though much larger charges are sometimes worked. The vats are best furnished with a central discharge, around which a filter-bottom is arranged in the shape of a very flat funnel. The filter-cloth is kept in place by ropes driven into grooves around the discharge-hole and inner periphery of the tub, near the filter-bottom. The vat is provided with an outlet under the filter, and has a slight inclination towards this point.

The charge of roasted ore is leached with water to remove the soluble base-metal salts. Water does not dissolve silver chloride, but a concentrated solution of base-metal chlorides does, and it is therefore advisable not to make the leaching-vats too deep, as otherwise a too concentrated base-metal solution is produced by the water in descending through a thick layer of ore. The base-metal leaching is completed when a few drops of calcium polysulphide poured into some of the outflowing solution does not produce a precipitate. This part of the process, according to the character of the ore, takes 4, 8, or 10 hours.



With the San Francisco del Oro ore, which filters well, the rate of filtration during base-metal leaching was 1 inch in 6 minutes or 10 inches per hour. With a vat 10 feet 2 inches in diameter, representing a filtering surface of 81.01 square feet, and a thickness of charge of 2.41 feet, the above rate was equivalent to 67.24 cubic feet, or 504.3 gallons per hour; leaching time, 8 hours = 4,034.4 gallons; 2 feet of water in the vat into which the ore is dumped = 1,215.2 gallons extra. Second washing, rate of filtration, $8\frac{3}{4}$ inches per hour; time, $1\frac{1}{2}$ hours = 647.1 gallons. Total for one charge of 8.39 tons, 5,896.7 gallons, or 703 gallons for each ton of ore. It has been mentioned that, on account of the roasted ore containing considerable caustic lime, it was not moistened as usual on the cooling-floor but dumped dry and hot into about 2 feet of water in the vat. Besides other advantages, this way of charging shortens the base-metal leaching time by nearly an hour, without reducing the rate of filtration. When the charge is in, the water ought to cover the ore about 1 inch. Leaching is then commenced from below,* and the solution diluted above. As soon as the solution is allowed to flow out below, a stream of clear water has to be turned on above and continued for about an hour, in order to produce a greater dilution. Then the influx is interrupted until the water sinks to the level of the ore, when water is again allowed to flow in. The base-metal solution of the del Oro ore shows an acid reaction. The leaching with water is continued until a few drops of calcium sulphide added to the solution produces only faint white clouds. These white clouds continue to show for hours, and are caused by the reaction of calcium sulphide and sodium sulphate precipitating gypsum. It takes a long time to leach alkaline salts contained in porous substances, thus it happens that while all the soluble metal salts have been dissolved and removed, the outflowing solution still contains and continues to contain sodium sulphate.

From a chemical standpoint, it would be advisable to continue leaching with water till all the sodium sulphate is removed, but in practice this would delay the process too much, and the silver leaching is therefore commenced as soon as all the heavy metal salts are removed. The sodium sulphate which still remains in the ore after leaching with water, enters the stock solution during the subsequent silver leaching. This has not a very injurious effect if calcium sulphide is used as a precipitant, because sodium sulphate is decomposed and gypsum precipitated.

The stock solution is therefore freed from sodium sulphate after every

* This is done to precipitate on to, and through the ore any chloride of silver that might be dissolved by a too concentrated solution of the base-metal chlorides.

precipitation, and the only resulting disadvantage will be that the precipitate will contain more gypsum. But if sodium sulphide is used as a precipitant, the effect of the sodium sulphate is very injurious, as it remains and accumulates in the stock solution and soon reduces its dissolving energy for silver chloride, rendering a prolonged leaching with water necessary. By inserting, in the outlet of the vat, a small rubber tube (provided at the end with a glass tube drawn to a fine point), and by leaving this tube in the outlet during the whole time of base-metal leaching, Mr. Hofmann obtained from the outflowing solution a very fine stream which, collected in a proper vessel, gave a true sample of the solution of about 3 or 4 gallons. This sample contained in 1,000 cubic centimetres:—

	Grammes.		Grammes.
Silver	0·0036	Lead	—
Cadmium	0·806	Sulphuric acid ...	18·708
Zinc	2·105	Chlorine	7·173
Iron	0·008	Lime	0·754
Copper... ..	Trace		

Silver Leaching.—The base-metal salts being removed, a stream of diluted solution of sodium hyposulphite is allowed to enter on top of the ore, which readily dissolves the silver chloride. When the outflowing solution shows indications of silver, the stream is conveyed to special precipitating-tanks, in which the silver is precipitated as silver sulphide by an addition of calcium polysulphide or some other reagent.

To ascertain the exact time when the hyposulphite solution, which follows the water, commences to appear at the outlet, a matter of importance, it is ordinarily tested with calcium polysulphide, and some operators indulge in the bad habit of testing it with the tongue, and are guided by the sweetish taste which the solution has if it contains silver. The following test is much superior, and is very sensitive and convenient:—A small strip of starch paper is dipped into a solution of iodine and then held in the outflowing stream. If the blue colour disappears it is a sign that the liquid contains a hyposulphite salt, and the stream must be turned into the precipitation-vats. The test is only applicable, however, when the base-metals are leached with cold water, as hot water discolours the blue paper. To facilitate and hasten the settling of the silver precipitates, the precipitation-tanks are provided with machine stirrers, by which the solution can be vigorously agitated.

After precipitation, the sodium hyposulphite solution is decanted after the precipitate has settled in tanks placed at a lower level. From these tanks the clear solution is pumped up to storage-tanks and

is ready to be used again. When all the soluble silver is extracted, the solution of the hyposulphite is allowed to run out till it disappears under the surface of the ore, when clear water is introduced again to displace all the hyposulphite solution; after this second leaching with water, the tailings are sluiced out through the central discharge, and the tank is ready for another charge of ore. The time for silver leaching varies according to the character of the ore from 8 hours to 2 or 3 days.

In the ordinary lixiviation process, calcium sulphide is the ordinary and best precipitant. This salt, however, cannot be used for that purpose in the Russel process, and sodium sulphide therefore takes its place. In the Kiss process the ore is leached with calcium hyposulphite, and the silver is precipitated with calcium sulphide. Leaching with sodium hyposulphite and precipitating with calcium sulphide (the ordinary method) is really a combination of the Patera and Kiss processes. When enough silver precipitate has accumulated on the bottom of the precipitating-tanks, it is drawn off and generally strained through a filter-press. The black silver cakes are then taken out, dried in a warm room or drying-oven, and introduced into a muffle or calcining-furnace to burn off the sulphur. After the blue flame has disappeared, heating must continue for several hours at a dark red heat.

The roasted cakes may be melted with lead in a cupelling-furnace, and refined or melted in graphite crucibles, in lots up to 300 lbs. in weight. What sulphur remains must be removed by melting it off with metallic iron introduced into the pot, an iron matte being formed, which rises to the surface and is skimmed off. The surface of the silver is then cleaned by adding some bone ash and borax, or borax alone, which is also skimmed off, and the silver dipped out or poured into moulds.

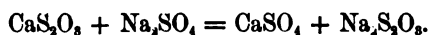
The quantity of hyposulphite solution required for treating the San Francisco del Oro ore is as follows:—The diameter of the vat is the same as for base-metal leaching (previously described), viz., 10 feet 2 inches. Rate of filtration, $8\frac{2}{3}$ inches per hour or 57.52 cubic feet or 431.4 gallons per hour. Time of silver leaching, 4 days or 96 hours or 41.414 gallons per charge of 8.39 tons, or 4,935 gallons for each ton of ore, 658 cubic feet.

At the Cusi mill, Mr. Hofmann states the vats are 12 feet in diameter, taking a charge of about 8 tons of ore. At a filtering rate of 8 inches per hour the volume of outflowing solution amounts to 74.6 cubic feet per hour, or 3,058.6 cubic feet in 41 hours for a charge of 8 tons, or 382.3 cubic feet or 2,867 gallons per ton of ore, employing the Russel process, taking the figures given by Mr. Stetefeldt. Mr. Hofmann, however, states

that he found the average leaching time at the Cusi mill to be 53 hours, which at the filtering rate of 8 inches per hour gives 494·2 cubic feet or 3,706 gallons per ton of ore.

The Stock Solution.

Mr. Hofmann appears to have been the first to introduce the practice of using sodium hyposulphite as a solvent and calcium sulphide as a precipitant. Calcium sulphide contains a considerable amount of (about 6 per cent.) calcium hyposulphite, even if freshly prepared, which in precipitating is introduced into the stock solution. It was therefore supposed that by using calcium sulphide as a precipitant the stock solution would be gradually converted into a solution of calcium hyposulphite, but Mr. Hofmann denies that this is the case, and states that the stock solution remains as sodium hyposulphite. He explains it in this way: At the time when base-metal leaching is usually interrupted, the ore still contains sodium sulphate. Calcium hyposulphite and sodium sulphate form sodium hyposulphite and calcium sulphate, which precipitates



If therefore the stock solution after precipitation, containing calcium hyposulphite, is rinsed, and comes in contact with the sodium sulphate contained in the roasted ore, the outflowing solution will have its calcium hyposulphite substituted by sodium hyposulphite, leaving the precipitated gypsum in the ore.

Thus the stock solution, even after continued use, still consists of sodium hyposulphite. It takes longer boiling to manufacture calcium sulphide than to prepare sodium sulphide, but $3\frac{1}{2}$ to 4 hours' boiling is sufficient, and the consumption of steam is small to maintain the solution, once it is boiling, at that temperature. The calcium sulphide appears to have the great advantage that it frees the stock solution from the very injurious presence of sodium sulphate, for if calcium sulphide is brought in contact with sodium sulphate, sodium sulphide is formed, which goes into solution, and the calcium sulphate is precipitated; thus all the sodium sulphate which the stock solution receives from the ore during lixiviation is decomposed, while sodium sulphide if used as a precipitant not only leaves the sodium sulphate undecomposed, but even furnishes an additional supply of this salt, and assists in charging the stock solution with it, diminishing its dissolving energy for silver chloride, and causing quite a large consumption of sodium hyposulphite.

If in preparing calcium sulphide, boiling is not continued beyond 3 or 4 hours and precipitation is properly executed, the original stock

solution can be maintained effective for several years without adding any fresh sodium hyposulphite to it. It will be even found that the solution increases in strength, and in order to keep it at standard strength it requires to be diluted from time to time with water. This cannot be accomplished if sodium sulphide be used. The loss of hyposulphite by decomposition and other causes is in fact more than replaced by the supply derived from the precipitant.

Mr. Hofmann gives a table* showing the tendency of the sodium hyposulphite solution to increase in strength, as above explained, and remarks that it is quite an important financial item whether its standard strength (0.50 per cent.) is kept up by adding water or sodium hyposulphite. At the Cusi mill, he used 765 lbs. of sodium hyposulphite for the preparation of the stock solution, working with it 2,011 tons of ore, and left the solution in perfectly good condition, only a little stronger than when originally prepared, without adding any extra sodium hyposulphite, while Mr. Daggett, who used sodium sulphide, reports a consumption in the Cusi mill of 3 to 7 lbs. of sodium hyposulphite per ton of ore.

Mr. Hofmann states that in working 2,011 tons of Cusi ore containing 45.2 ounces of silver per ton, the cost of calcium sulphide per ton of ore was as follows :—

					Cents.
Sulphur, 3.92 lbs. at 7 cents	...	...	...	...	27.4
Lime, 8.25 lbs. at 1 cent	...	...	...	...	8.2
Total	...	...	...	...	35.6

or 28.7 cents less than the cost of sodium sulphide (reckoned at 64.3 cents) treating an ore containing 35.1 ounces of silver. Reducing the above figures to what they would be in working an ore containing 35.1 ounces of silver per ton, they would stand :—

					Cents.
Sulphur, 3.02 lbs. at 7 cents	...	...	...	...	21.1
Lime, 6.40 lbs. at 1 cent	...	...	...	...	6.4
Total	...	...	...	...	27.5

or 36.8 cents less than the cost of sodium sulphide, which is equal to a saving of 57.2 per cent. Taking into consideration the fact that the use of sodium sulphide causes also a consumption of 3 to 7 lbs. of sodium hyposulphite per ton of ore, it is apparent that sodium sulphide is more expensive, and that calcium sulphide is preferable as a precipitant, regardless of other advantages, for the important reason that it keeps the stock solution free from sodium sulphate.

* *The Engineering and Mining Journal*, New York, vol. xlvii., page 236.

The calcium polysulphide is manufactured at the works, by boiling 2 parts of the fresh lime with 1 part of pulverized sulphur in water for 3 to 4 hours, in deep tanks made of boiler iron, into which steam is directly introduced. The consumption of sulphur is from 2 to 7 lbs. per ton according to the ore.

The Precipitate.

Mr. Hofmann gives the analysis of two different lots of roasted precipitate of del Oro ore:—

	Per Cent.	Per Cent.		Per Cent.	Per Cent.
Gold ...	0·04	0·014	Zinc ...	4·30	13·86
Silver ...	19·00	21·60	Lime ...	3·88	3·62
Lead ...	30·64	21·10	Sulph. acid	6·10	6·18
Copper	11·55	4·44	Sulphur	14·90	19·37
Cadmium	3·45	1·20	Insoluble	5·45	4·96
Iron ...	0·72	2·68			

The two lots of precipitate differ, as will be seen, considerably with regard to lead, copper, cadmium, zinc, and sulphur, due partly to variations in the character of the ore, of which the precipitate is the resulting product, and to a great extent to variations in roasting.

The quantity of sulphur depends on the length of time the precipitate is subjected to roasting in the reverberatory furnace. To avoid loss by volatilization, the precipitate was left in the furnace only until the blue sulphur flame ceased. The percentage of lime (3·88 to 3·62) is in both lots nearly the same, and shows that the value of the precipitate is not depreciated, by using calcium sulphide as a precipitant, enough to make its use objectionable. The dried precipitate contains 47·96 per cent. of sulphur. Experiments to regain the surplus sulphur by boiling the fresh precipitate with caustic soda gave very satisfactory results. They showed that 60 per cent. of the sulphur originally contained in the precipitate can be thus regained and brought into a state in which it can be directly used again as a precipitant.

Using Cupric Chloride for Badly-roasted Charges.

If an insufficiently chloridized ore be treated during base-metal leaching with a dilute solution of cupric chloride it has a very beneficial effect, as stated elsewhere, and Mr. Hofmann, in some instances, obtained a further extraction from the del Oro ore of 34 to 40 per cent. of the silver by its use. 35 lbs. of bluestone and about 70 lbs. of salt, boiled by steam for

about 15 or 20 minutes, gave a sufficient quantity of cupric chloride for a charge of $8\frac{1}{2}$ tons, at a cost of 60 cents per ton of ore:—

	Dollars.
Bluestone, 35 lbs. at 12 cents ...	4.20
Salt, 70 lbs. at 1.7 cents ...	0.88
... Total ...	5.08, or 0.60 cents per ton.

The cupric chloride is either added to the water contained in the tank, into which the dry and hot ore is dumped, or it is added during base-metal leaching. In the latter case it is better to apply the copper solution after the main portion of the base-metal salts have been leached out, say about 1 hour after commencing base-metal leaching, and to add it gradually in order to penetrate the whole charge. To about 6 or 8 inches of water standing above the ore, one quarter of the prepared copper solution is added, stirred, and allowed to sink through the ore. As soon as the liquid is level with the top of the ore, the outlet under the filter is closed, and again 6 or 8 inches of water is allowed to flow into the vat, to which the second quarter of the copper solution is added; this is repeated a third and fourth time, and the charge is washed in the usual way.

The first method is quicker and less troublesome, but in this case leaching from below is advisable. The solution from the del Oro ore treated in this way left the tank colourless with only a slight reaction for copper, showing that the cupric chloride was decomposed in passing through the ore. Mr. Hofmann believes that if the roasted ore of the Yedras mine were treated in this way, very good results would be obtained, without reducing the fineness of the precipitate as much as is done at present by the use of extra solution.

COST OF LIXIVIATION.

The works at Parral have two leaching-plants, one in connexion with the modified Howell furnace and the other with the reverberatory furnaces. Separate accounts were kept of each. The following figures refer to the Howell plant. For the consumption of sulphur no separate account could be kept, and the quantity used per ton is therefore calculated on the total amount consumed and the total number of tons of ore leached in both mills. It gives a consumption of 7 lbs. per ton of ore. One man was employed roasting the precipitate obtained from both plants, and one-half of his wages is charged in the statement. A reduction of cost, it is stated, could be effected if the precipitate were boiled with caustic soda, instead of roasting it. The item of management, office, etc., represents one-third

of the cost for 100 tons per day, calculated proportionately on $8\frac{1}{2}$ tons, as explained in the cost of roasting :—

	Dollars.
Labour for charging and discharging	1·00
Two leachers at 1·00 dollar	2·00
One man preparing calcium sulphide	0·75
Sulphur, $59\frac{1}{2}$ lbs. at 6 cents	3·57
Lime, 180 lbs. at 0·5 cent	0·90
One man roasting precipitate at \$1·00 (one-half)	0·50
Wood for roasting precipitate	0·50
Management, office, mechanics, assay office	1·78
Oil, light, filter cloth, shovels	1·50
Steam for pump, and sulphide solution were charged to roasting	—
Total cost	12·50

or cost of leaching per ton of ore, 1·47 dollars, Mexican currency.*

Total cost of reduction, not including stamping :—

	Dollars.
Roasting in the reverberatory furnace ...	3·67
Lixiviation	1·47

Mexican dollars 5·14 per ton of ore.

Mr. Hofmann noticed that heavy brown fumes were emitted from the ore in roasting it in the muffle furnace under certain conditions, and was led to suspect the presence of cadmium in the del Oro ore in considerable quantities. Further investigations proved this to be the case. The cadmium leaches out along with the zinc, and as long as there is zinc in the solution, cadmium will be found. The fact that the cadmium is brought into solution by the regular operation of the process for extracting the silver, permits of its extraction (as a bye-product) at very small cost.

The analysis showed that the base-metal solution of the del Oro ore is remarkably free from metals which are precipitable by zinc; if, therefore, the more concentrated part of the base-solution be conveyed into tanks (like those devised and recommended by Mr. Stetefeldt), for precipitating the copper and silver of the base-metal water with scrap-iron, and metallic zinc is introduced, it will precipitate the cadmium, copper, and silver. The base-metal solution is acid enough, but the addition of some sulphuric acid hastens the process.

It is more profitable to manufacture cadmium sulphide than to produce the metal. The metallic precipitate, after being washed, is boiled with dilute sulphuric acid. Cadmium dissolves, while the copper will remain

* The Mexican dollar was at the time in question, the writer believes, worth, 3s.; at present it is worth 2s. 9d.

as a sediment; and so will lead if it be present. The solution is decanted, filtered, and the cadmium precipitates as cadmium sulphide by sulphuretted hydrogen. Cadmium sulphide is a brilliant and valuable paint. Experiments on a large scale showed that from 2 to 3 lbs. of cadmium sulphide could be precipitated from the base-metal solution derived from a ton of ore.

The best orange-yellow of cadmium is obtained by precipitating with sodium sulphide, but the solution must first be made alkaline with caustic soda.

Mr. F. M. Watson in a letter to *The Engineering and Mining Journal*, New York, of April 8th, 1893,* speaking of the Russel process at Sombrerete, Zacatecas, says:—The ore runs roughly 10 per cent. of blende, 10 per cent. of galena, 30 per cent. of iron pyrites, and the rest mostly quartz containing on an average about 20 per cent. of sulphur. The old reverberatory furnaces used for roasting (taking six months' average) showed a roasting chlorination of 88·5 per cent., but the loss from volatilization was very heavy (the last six months' average being 16·6 per cent., and before it had risen to as high as 24 per cent.). By considering the two losses Mr. Watson therefore places their efficiency at 73·8 per cent. The extraction of sulphides during this period was about 73 per cent., and the total cost, including grinding, was about 8 dollars, Mexican currency, per ton, crushing with rolls. He advocates using stamps in place of them. The ordinary Stetefeldt furnace also does not appear to have been more successful in this case than with the San Francisco del Oro ore, but Mr. Watson considers that it might be modified to give good results, and he considers that with a remodelled mill 85 per cent. of the raw ore value could be extracted at a cost of not more than 6 dollars, Mexican currency, per ton.

TROUGH-LIXIVIATION.

This system is a continuous one—a modification of tank-lixiviation—the chemical reactions are the same, but the time of leaching is enormously shortened, and the manipulations are simpler and more labour-saving. It is particularly adapted for large works, and for ore which on account of lead requires a long leaching time.

While the silver from all the other silver-bearing minerals can be easily and quickly extracted as chloride, that portion contained in the galena dissolves very slowly. The larger portion of the silver may be in fact extracted in a few hours, while the remainder will take days. The

* Page 316.

roasted del Oro ore, for example, filters quickly, but if the ore contain 10 to 11 per cent. of lead, the silver-leaching time is 4 days, and if it contain 15 to 17 per cent. of lead the time is increased to 5 or 6 days.

A description of trough-lixiviation is given by Mr. Hofmann in *The Engineering and Mining Journal*, New York, of September 10th, 1887, November 26th, 1887, and March 16th, 1889,* from which these particulars are taken. Silver chloride contained in roasted ore almost instantly dissolves if rapidly brought in contact with a proper volume of moving sodium hyposulphite solution. No more than $\frac{3}{4}$ to $1\frac{1}{2}$ minutes are required, and it is rather the quantity or volume than the concentrated state of the liquid solvent, that produces this effect; it is in fact the principle upon which the process depends.

In the tanks the amount of solution which comes in contact with the ore is regulated by the latter's filtering capacity. The operator can slightly increase the speed of filtering and so increase the quantity of solution used, by producing a vacuum under the filter bottom, but he cannot produce and maintain at will a certain favourable proportion of ore and solvent, which is of such importance for a quick and thorough extraction. If, however, the ore be introduced into a running stream of the solvent, the operator has it in his power to produce and maintain any desired proportion.

Instead of charging the ore in tanks, and permitting the solvent to filter through, it is dissolved outside the tanks in troughs, while the ore is moving in and with the stream of solvent, and the tanks are only used for the separation of the solid from the liquid. The ore from the furnaces is dumped into bins, from which it is mechanically and evenly charged into a perpendicular square tube 12 by 12 and about 2 feet in height, which is crossed by several sprays or sheets of water, closing it near the top and bottom. The dust caused by the contact of hot ore and water is absorbed by the top and bottom sheet of water, and cannot escape, while the steam generated is condensed.

The pulp, when leaving the perpendicular tube, enters a grinding machine of similar construction to the German kegelmühle, an arrangement which answers better than an agitator, which was first proposed for the purpose of mixing the ore with water (to prevent it being carried down the trough in bulk), and to mash and grind up any lumps it contains. The mill discharges the pulp into the base-metal leaching-trough of triangular section, which leads to the settling-tanks.

*Pages 185, 393, and 255 respectively.

By this system, the whole cooling-floor manipulations are avoided, likewise the filling of cars on the cooling-floor and the transportation of the moistened ore to the tanks, also the shovelling out of the tailings from the tanks, which is a great saving of manual labour, without involving much extra machinery. It requires two men per shift to bring the ore from the furnaces to the bins, one man in the base-metal department, and one man and a helper in the silver-leaching department. The stirring of the silver solution in precipitating is done by mechanical stirrers, which do excellent work.

The rapidity of the extraction requires quicker circulation of the solution entailing the use of a larger pump; but Mr. Hofmann considers the extra expense of this a very small drawback. The hot ore warms the water for base-metal leaching, without incurring extra expense or labour.

The proportion of water depends on the amount of base-metal chlorides contained in the ore, and has to be so regulated that the resulting base-metal solution is too dilute to dissolve silver chloride. This is easily arranged, by gradually increasing the stream of water while maintaining the same supply of ore, and testing the resulting solution for silver.

The length of the trough depends on the character of the ore, but 150 feet from the mill to the first tank will, in most cases, be sufficient. The inclination should not be less than $\frac{3}{4}$ inch to the foot. The trough can be arranged in zigzag, but has to lead over all the tanks.

In the line of the trough above each tank there is a square box, 14 by 14 by 10 inches, the bottom of which is provided with a plug-hole in order to permit of any desired tank being charged.

The tanks have in the centre of the bottom a sluice-hole 6 inches in diameter, to which is attached to the outside by means of a flange a short piece of cast-iron pipe of about the same diameter. This pipe is like a gas-pipe elbow, and can be tightly closed by pressing a rubber gasket against the outside flange. This valve is worked from a platform alongside the tanks. This pipe must be well coated with asphaltum varnish. Around the sluice or discharge-hole the filter is arranged in funnel-shape, having an inclination of $\frac{3}{4}$ inch to the foot. The filter-cloth must be well fastened round the outer and inner circle. The central position of the discharge-opening and funnel-shape of the filter-bottom permit of quick and perfect sluicing. A tank with a level filter-bottom, if large, can be sluiced clean through a side gate. The space below the filter is provided with the usual outlet-pipe. Close under the filter is inserted from outside a $\frac{3}{4}$ inch pipe which, connected with 1 inch hose, reaches the rim of the tank for the escape of the air. Before the tank is

used for operation, a wired rubber-hose is connected with both the water and the solution-pipes, and so placed from above that the lower or outlet end enters the discharge-pipe through the central hole in the bottom. The object of this hose is to inject a stream of solution at the bottom of the ore (in the outlet-pipe), when the tank is to be sluiced out for silver leaching.

The stream undermines the tightly-packed ore which gradually caves in, until a funnel-shaped opening is made through its depths. Then one or more streams are allowed to play on top of the ore until it is all sluiced out. The hose in the discharge-pipe—which must be stiff in order not to be flattened—is allowed to remain, in order to prevent the discharge-hole from being clogged by a too sudden rush of ore. Before starting the operation the discharge-pipe is filled with water through the central hose, the lower end being covered, in order to keep it filled with water to prevent obstruction from the ore.

The tanks are placed on the same level in two rows close together, and are connected by pipes in such a way as to permit of any desired tank being disconnected without disturbing the communications of the others. The connecting-pipes are also on a level, placed a few inches below the rim of the tanks, and well coated with asphaltum varnish. Their diameter depends on the capacity of the works. Each tank is provided with an outlet (on the level of the connecting-pipes), which discharges below the bottom into the base-metal trough, the latter being connected with the outlet-hose from under the filter-bottom. The connecting-pipes and upper outlets can be closed with wooden plugs from the inside of the tanks.

Base-metal Leaching.—At starting, the stream of roasted ore and water, after having passed through the whole length of the base-metal leach trough, is allowed to enter the tank by opening the hole in the bottom of the small square box which intersects the trough above the tank. The ore will gradually fill the first tank, while the base-metal solution after reaching the level of the connecting-pipe will flow into the next tank, and when this is filled, into the next tank, and so on through all the tanks until it finds the outlet of the last tank, through which it will discharge into the base-metal trough. The motion of the solution in each tank is so slow that, by the time it reaches the last outlet, it is clear. A board, placed edgewise a few inches below the surface and across the tank, will prevent the formation of a diametrical stream from one pipe to another, and greatly assist in clearing the solution. If the proper proportions of water and ore have been used, the base-metal

solution will not contain any silver, and can be allowed to run to waste. When the first tank is filled with ore, the connecting-pipe is closed, and stream of pulp transferred into the second tank, all other connexions remaining unchanged. The outlet-hose below the filter-bottom of the first tank is now opened, and the solution still contained in it is allowed to drain off. As soon as it disappears below the surface of the ore some clear water is added to force out the remainder of the base-metal solution. The first tank is now ready for silver leaching.

Silver Leaching.—In their passage through the trough from the mill to the tanks, all the soluble base-metal chlorides have dissolved, and the charge of the first tank having been treated, as above described, is now ready for silver leaching. The rubber gasket of the discharge-pipe is pulled back, and sodium-hyposulphite solution is turned on through the central hole, and the whole charge sluiced out. Ore and hyposulphite solution discharge into a trough under the first and last tanks, which are connected with the silver-leach trough. At first, before other streams of hyposulphite solution can be played on the surface of the ore, the pulp is diluted by an extra stream in the silver-leach trough. Ore and solution now pass through a trough, not less than 150 feet long, to a similarly arranged set of tanks.

When the pulp reaches the first tank, the solution has dissolved all the silver chloride, and the sand drops as tailings into the tank. The silver solution has also to pass through all the tanks and leaves the last one clear. It is conveyed to the precipitation-tanks. When one tank is filled with tailings, it is disconnected from the others, and the pulp allowed to flow into the next one. The outlet-pipe under the filter-bottom is opened, the remaining silver solution allowed to drain off, and the part retained by absorption displaced by water. Where water is scarce, the base-metal solution can be accumulated in the outside storage-tank and used for sluicing the tailings. The proportion of solution and ore to be used depends on the nature of the ore, and has to be ascertained for each kind. Ore containing lead requires most solution. It is best to determine the proportion in weights, as it makes it easy to calculate the required capacity of the different tanks, pipes, and pumps, for a given capacity of mill.

Mr. Hofmann's tests, he states, show that the minimum quantity of solution required is 3 to 5 times the weight of the ore, and the maximum 18 to 20 times. The weight of the solution is, for convenience, taken as equal to water, 1 cubic foot = 62·5 lbs. In most cases 10 parts of solution to 1 of ore will be sufficient. Assuming this proportion, and

taking 1 cubic foot solution as 7·5 gallons, and 1 gallon as 8·33 lbs., we find that in order to lixiviate 40 tons per day, it will require 3,200 cubic feet or 24,000 gallons of solution to be daily pumped to the upper reservoir and circulated. This, theoretically, would require a pumping capacity of 16·66 gallons per minute, and precipitating facilities for 1,000 gallons per hour. By erecting a temporary trough of not less than 150 feet in length, and a mixing-box at the upper end, the required proportions of solution and ore can readily be determined by a series of experiments. The samples have to be taken at the lowest end of the trough, while the pulp is dropping into the receiving-tank. The vessel with which the sample is caught must be large enough to receive the whole stream during the time the sample is caught. Sufficient time must be allowed for the ore to settle. The clear solution is carefully decanted, and the sediment placed on a filter, washed well with water, dried, and assayed. Before subjecting it to the solution-test, the ore has, as a matter of course, to be treated with water to remove the base-metal chlorides.

Mr. Hofmann states the advantages of trough-lixiviation as follows:—

At first sight it would appear that very dilute silver solutions are obtained, and have to be treated in the precipitation-tanks. This, however, is not the case. The resulting silver solution maintains a uniform strength in silver and other soluble metal salts, and is of about the same strength as the whole filtrate of one charge in tank-leaching would be, if accumulated in one precipitation-tank. In tank-lixiviation very strong solutions are formed at the beginning, and very dilute ones towards the end, and as it frequently happens that a tank-full of such very dilute solutions has to be precipitated by itself; a uniform strength is in fact by far preferable.

This method of lixiviation allows the operator to bring the ore in sudden contact with any desired quantity of the solvent, and offers the means in this way, of overcoming some very annoying chemical and mechanical difficulties encountered in other lixiviation processes. Lead sulphate reduces the dissolving energy of sodium hyposulphite for silver, and this is why the lixiviation of lead-bearing ores is so exceedingly slow and requires such an extensive plant.

In the ordinary lixiviation, the solution becomes more saturated with lead sulphate as it descends through the ore and loses proportionately its dissolving energy. As the solubility of the lead sulphate increases with the concentration of the solution, a stronger solution does not hasten the process; but if the ore be brought rapidly into contact with a large volume of hyposulphite solution, the latter retains enough of its dissolving

energy to produce a quick extraction. The presence of lead sulphate therefore does not retard trough-lixiviation, it merely entails the use of larger quantities of solvent. The rapidity with which the silver dissolves, also materially lessens the unfavourable influence of caustic lime. The possibility of bringing the ore into contact with any desired quantity of the solvent has the further advantage of preventing the base-metal solution from dissolving silver. The resulting solution need only be sufficiently dilute. It does not take much more water than in the ordinary leaching, when the bulk of the silver is dissolved by the base-metal chlorides, while the solution is very concentrated. Shortly after the beginning, no more silver is dissolved; if, therefore, the charge of ore could have been brought at once into contact with the whole quantity of water used in washing, Mr. Hofmann thinks much less silver would go into solution. Clayey ores and flue-dust may be successfully treated by trough-lixiviation regardless of their filtering property.

In ordinary leaching, each tank-charge is in a different stage of the process, and this necessitates great care and attention and keeping a separate record of each tank. In trough-lixiviation, the operation being continuous, attention need only be concentrated on one tank in each department to prevent it from being overcharged. Although the process is divided into two departments (the base-metal and silver leaching) the manipulation is materially simplified, the tanks being charged automatically by the stream of the respective solutions, and the costly handling in cars is obviated. Leaching works built on this plan will require more grade, and it will be preferable to have the roasting and base-metal leaching done in the main building; and the silver settling and precipitation-tanks, with all the other apparatus required for the final treatment of the precipitate, in a separate department lower down; the two being connected by the silver-leach trough.

The principle of this method can be tested in the laboratory by introducing 20 grammes of roasted ore, which has previously been washed into a graduated cylinder of 1,000 cubic centimetres, in which is contained 200 cubic centimetres of sodium hyposulphite solution. The top of the cylinder has to be tightly closed with the palm of the hand, and the glass brought into a horizontal position and oscillated, in order to make the ore and solution pass quickly from one end to the other to imitate the current in a trough. After the oscillating motion has been continued for about 2 minutes the contents of the cylinder are emptied into a filter, and washed with water to displace the silver solution from the sand and filter-paper.

It will be found that all the extractable silver has been dissolved, and the residues will correspond with those obtained in the regular chlorination assay. If the result of a first trial be not satisfactory, it is due to a fault in the quantity of solution, more of which must be used in the next test, and so on, till the results are accurate and the required proportions of solution and ore are ascertained.

Trough-lixiviation was first used in the mill of the North Mexican Mining Co., Cusihuriachic, Chihuahua, Mexico. This mill was originally arranged for tank-lixiviation, but the ore hardened like cement, and did not permit any solution to pass through. Trough-lixiviation, however, enabled the ore to be worked rapidly, and the resulting tailings agreed with the chlorination test.

Mr. Hofmann gives a number of experiments and details with regard to trough-lixiviation in *The Engineering and Mining Journal*, New York, of March 16th, 1889,* and in the *Transactions of the American Institution of Mining Engineers*, February, 1888.† These cannot, however, be reproduced here in detail. As the saving in time is, however, one of the chief claims of the process, the writer may instance some comparative figures Mr. Hofmann gives, comparing it with tank-lixiviation treating del Oro ore :—

Time taken in tank-lixiviation :—

	Hours.
Charging	3
Base-metal leaching	8
Expelling the water by solution	1
Silver leaching	96
Expelling the solution by water	1½
Total	109½

Time taken in trough-lixiviation :—

	Hrs.	Min.
Base-metal leaching and filling the tank	3	6
To drain the wash-water from the top of ore	0	34
To expel the base-metal solution by water	3	25
To expel the water by hyposulphite solution	1	20
Silver leaching (sluicing with solution)	3	36
Draining solution from top of ore	0	34
Expelling the solution by water	2	30
Total	15	5

Treating the del Oro ore by trough-lixiviation, Mr. Hofmann found in silver leaching that, using a solution with a strength of 0·50 ounce per ton, the best results were obtained with the proportion of 1 of ore to 3·4 of solution or 108·8 cubic feet or 816 gallons of solution in circulation

* Page 255.

† Page 662.

per ton of ore treated. But in trough-lixiviation, 658 cubic feet, or 4,935 gallons of solution were required per ton. The proportion of 1 to 3·4 gave tailings carrying only 3·59 ounces per ton. In evidence of the statement that by producing a sufficiently dilute base-metal solution it will not contain any silver and may be allowed to run to waste, Mr. Hofmann cites the following test :—One litre of the 702 gallons of base-metal solution was precipitated with calcium sulphide. The precipitate, after fluxing and treating like an ordinary ore assay, returned no more than 0·0002 gramme of fine silver, 702 grammes will therefore contain 0·532 gramme, which represented the total amount of silver dissolved from 8·39 tons of ore, or 0·06 gramme or 0·002 ounce of silver per ton, which is practically nothing.

Other points mentioned are, while in tank-lixiviation the rate of filtration was 8½ inches per hour, in trough-lixiviation it was 12 inches per hour. The number of tanks required in trough-lixiviation is much less than in tank-lixiviation, and while the roasted sulphides obtained from the trough-process contained 20·9 per cent. of fine silver, those obtained from the tank-process during the same week and from the same lot of ore only contained 17 per cent. fine silver.

Some of the most interesting figures may be summed up as follows :—

	In Tank-lixiviation.	In Trough-lixiviation.
Quantity of water required for base-metal leaching, including sluicing, per ton... ..	943 gals.	1,129 gals.
Quantity of hyposulphite solution which has to circulate for each ton of ore	4,935 „	816 „
Time required to treat one tank-charge of ore ...	109 h. 30 m.	15 h. 5 m.
Total quantity of water required for 100 tons of ore per day	94,300 gals.	112,900 gals.
Total quantity of hyposulphite solution per day to work 100 tons	493,500 „	81,600 „
Loss of silver in base-metal leaching per ton of ore...	0·25 oz.	trace.
Extraction of silver in both methods the same.		

In connexion with the Hofmann gold-and-silver chlorination process, which has been mentioned in the earlier part of this paper, it is to be noted that after the silver has been extracted, the solution of hyposulphite used for leaching is allowed to run out till it disappears under the surface of the ore, when clear water is introduced, in order to displace the solution. The desilverized ore must then be removed from the tank to a dry-kiln, where it is left till the surplus water has evaporated. After this it is charged back into the tank still moist.

This second handling and drying cannot be dispensed with, as the ore after leaching is too wet to permit of the free passage of chlorine. If the

ore be cupriferous, much copper will be carried out with the gold solution (after it has been chlorinated), colouring it green.

An application of the leaching process to the pan-amalgamation of very base ores, which has been invented by Mr. Kustel, deserves notice. He states that it is applicable to silver ores, like those of Flint, Idaho, containing base-metals, and also to auriferous copper ores, which by their nature require roasting, as the amalgamation of gold is very much obstructed by the presence of copper salts. If there be soluble chloride of silver in the roasted ore, and besides this, soluble chlorides of copper, lead, antimony, and zinc, they will all, as a matter of course, be decomposed and amalgamated.

All take part in consuming and flouing the quicksilver and in destroying the pan, such a combination as the above hindering the amalgamation of the silver and gold. The base-metal chlorides being soluble in water, while the chloride of silver is not, it is a simple expedient to dissolve out these salts by leaching with hot water, and thus remove them from the ore, prior to amalgamation. The ore being thus divested of its rebellious features, gives excellent results in the pans.

LIXIVIATION *versus* AMALGAMATION.

In comparing the Russel process with amalgamation, Mr. Stetefeldt* enumerates the principal points in favour of lixiviation as follows :—

1. In amalgamation, the coarseness of crushing, without considering the question of roasting, is limited by the capacity of the settler to work off coarse sands without loss of quicksilver. In lixiviation pulverizing as coarse as possible is desirable.
The limit of coarseness depends on the character of the ore, and principally upon the manner in which the silver-bearing minerals are distributed in the gangue.
2. The original cost of the lixiviation-plant is much lower than that of pans and settlers, and a further saving is effected by a reduction in the size of engines and boilers.
3. In amalgamation the pans and settlers consume not less than $1\frac{1}{3}$ horse-power per ton of ore. The power for pumping solutions, etc., in the lixiviation process, is merely nominal.
4. In large mills the quantity of quicksilver in solution represents a capital of 30,000 to 40,000 dollars (£6,250 to £8,333 6s. 8d.), while the stock of chemicals required for lixiviation costs less than one-tenth of this amount.

* *The Lixiviation of Silver Ores*, page 4.

5. With the Russel improvements the percentage of silver extracted by lixiviation is in most cases higher than by amalgamation.
6. Lixiviation by the Russel process requires a less careful chloridizing-roasting, and in consequence a lower percentage of salt may be used in roasting.
7. Ores that can be successfully treated by raw amalgamation give often better results by lixiviation with extra solution.
8. The value of the quicksilver lost, and cost in wear and tear of the pans and settlers amounts to more than that of the chemicals consumed in the lixiviation process.
9. The lixiviation process permits of the extraction of copper and lead as valuable bye-products.
10. Amalgamation is invariably injurious to the labourers' health.
11. Where gold-bearing silver-ores have been roasted with salt, lixiviation extracts in many cases more gold than amalgamation.

The disadvantages of lixiviation as compared with amalgamation are:—

1. Lixiviation requires more chemical knowledge and a more careful supervision of the operations.
2. The handling of large volumes of solutions is a disadvantage common to all humid processes.
3. There is more danger of losing silver by careless manipulation, and by leakage of badly constructed plant.
4. In the lixiviation process the precious metals are obtained in the form of sulphides. The conversion of the latter into bullion, requires more skill and is more expensive than the handling of amalgam.

The chemistry of the process has been most ably discussed and dealt with by Mr. Stetefeldt and Mr. Ellsworth Daggett,* and treated of in the *Report of the Californian State Mineralogist*, 1888, which contains an independent article upon the hydro-metallurgy of silver, as well as a critical review of the Russel process by Mr. C. H. Aaron.†

The writer gathers from these various sources that it is with roasted ores which have an alkaline reaction caused by the presence of caustic lime (as, for example, the alkaline arsenical ores of Las Yedras, Sinaloa, Mexico,) that the Russel process, as compared with the ordinary Van Patena process (leaving the Kiss process out of the question), has

* *Trans. Am. Inst. Min. Eng.*, vol. xvi., page 362.

† Page 832.

achieved its greatest success, but it is possible that it may meet with a formidable rival in this province in the new departure of pyritic smelting.*

Looking at a number of examples that are given it would appear that the extraction in the mill by the Patera process shows a difference in certain instances, in favour of the Russel process, of 22 to 30 per cent. of the silver extracted.

A table given by Mr. C. H. Aaron also shows the results of a series of competitive mill-runs, extending over eight months at the Ontario Mill (on Ontario ore), in which the percentage extracted by the Russel process varied from 84.7 to 93.9 per cent. (or on the average about 91.17 per cent.) as against 65.3 to 84.9 per cent. (or on the average 77.4 per cent.) extracted by amalgamation, treating ore which ran about 47 ozs. per ton roasted. The tailings from the amalgamation still carried 10.76 ozs. per ton on the average, whilst the lixiviation-tailings only ran 4.3 ozs.

Experiments at the same works from November, 1887, to January, 1888, on an ore which ran 43.76 ozs. in silver, showed that 82.1 per cent. was extracted by amalgamation, as against 91.5 per cent. by the Russel process.

On the whole, however, taking the results of five different mills it would seem that whilst amalgamation gave an average of 80.7 per cent., the Russel process averaged 89.4 per cent., or 8.7 per cent. above the results of amalgamation, and 4.8 per cent. better than could be extracted with ordinary solution making the latter tests in the laboratory.

It is therefore to be inferred that, in the case of certain ores which have been specified, the Russel process extracts more silver than amalgamation, but it is to be also noted that in the case of four of the mills taken as examples, the percentage extracted by amalgamation is certainly 10 per cent. less than in many mills where roasting-milling is practised, and therefore cannot be altogether regarded as typical of the capabilities of the latter process in certain cases.

The ore, for example, of the Ontario mine is very base, containing, as before pointed out, zinc, lead, and silver sulphides, as well as chlorides, in a quartz gangue, and therefore the comparative success of the process in this instance, even from a purely chemical standpoint, scarcely fore-shadows it as a universal fact.

Next, as regards capital outlay, Mr. Stetefeldt gives the cost of a plant for dry-crushing and roasting 80 tons a day as follows:—

* It is to be regretted that more details of the cost and working of this process are not at present available.

	Weight in Lbs	Dollars.	£	s.	d.
Buck-eye engine, 72 to 121 horse-power	15,000 ...	1,775-00			
Knowles, feed-pump, No. 3	640 ...	275-00			
Heater	2,000 ... {	175-00			
Air-pump and condenser		450-00			
Two Krom rock-breakers	12,000 ...	1,500-00			
Three double-shelf dry kilns	70,000 ...	2,700-00			
Two sets Krom 26 inches rolls	29,000 ...	4,500-00			
Two Krom screens	1,200 ...	800-00			
Stetefeldt furnace	49,000 ...	3,000-00			
Hoist, with cage and safety-catches ...	2,000 ...	600-00			
Shaftings, bearings, pulleys, wire-rope transmission	18,000 ...	1,300-00			
Electric light plant, with separate engine for dynamos ... ..	... ..	1,700-00			
Belting ... ..	... ..	1,000-00			
Elevators, conveyors, feeders, hoppers, cone-pulley ... ..	... ..	1,000-00			
		20,775-00	=	4,328	2 6
Add the cost of four 40 horse-power high-pressure boilers ... ..	... ..	...			
Add the cost of the lixiviation-plant proper,* with a capacity of 80 to 170 tons of roasted and raw ore, if the tailings are removed by sluicing; 70 to 140 tons, if the tails are to be shovelled ... ..	... ..	6,772-70	...	1,310	19 7
Add the cost of painting vats and tanks with three coats of white paint, say, 746 lbs. of white lead and 41-7 gals. oil, occupying one man 34 days to lay on ... ..	... ..	...			
Add the cost of plant for refining sulphides by the humid process estimated (erected) at ... ..	... ..	5,000-00	...	1,041	13 4
Add the cost of grading and foundation to the mill structure and plant it contains (which it is only possible to figure in accurately by knowing the exact quantities of material and the time of skilled and ordinary workmen employed on the job) ... ..	... ..	...			

* This includes finished lumber and hoops for 6 lixiviation-tanks, 3 storage-tanks, and 6 precipitating-tanks, 1 sulphide storage-tank, 2 solution-sumps, cast and wrought-iron fixtures for vats and tanks, pipes, valves, steam-hose, 1 sodium sulphide mixing and 2 storage-tanks, 8 Korting ejectors, No. 4 Knowles fire-pump, (size A), for sluicing tails; Knowle plunger-pump for pumping solutions, 1 Johnson 18 inches filter-press, 1 Johnson pressure-tank, and a Knowles feed-pump, No. 2, for boiler.

dd finally freight and transport charges, depending on the locality, and it will be found that the total cost is not so far short of a pan-amalgamation plant of the same capacity as might be supposed

Now, let us glance at the working expenses of running a lixiviation-plant which are given by Mr. Stetefeldt for a mill of 80 tons capacity per day :—

	Cords of Wood.	Tons of Coal.
Fuel, engine and boilers*	5 to 6 ...	2½ to 3
Boiler lixiviating-building	3 ...	1½
Dry kiln ore and salt	3½ ...	1½
Stetefeldt furnace, depending on quality of wood and character of ore	6½ to 8½	
Sulphide refinery for roasting, refining, and melting bars in a reverberatory furnace	1	
Total ...	19 to 22	

The cost of labour per day would be as follows :—

	No. of Workmen.	Hours of Work.
Engine and boilers ...	2 engineers	12
" " ...	2 firemen	12
Ore-house ...	2 rock-breakers	10
" " ...	2 wheeling ore	10
Dry kilns ...	4 bringing ore from ore-house and charging kilns	12
" " ...	2 discharging kilns	12
" " ...	2 firemen also attending salt-kilns and assisting rolls	12
Rolls ...	2 machinists	12
Stetefeldt furnace ...	3 firemen	8
Cooling-floor ...	12 discharging, cooling, and charging vats	8
Lixiviations ...	2 lixiviators	12
" " ...	3 helpers	12
" " ...	2 precipitators	12
" " ...	2 firemen on boilers, pumps, and pipes ...	12
" " ...	2 handling sulphides	12
Refinery ...	2 roasters and refiners	10
Mill ...	1 night foreman	12
" " ...	1 machinist	10
" " ...	1 carpenter	10
" " ...	1 blacksmith	10
" " ...	4 general helps	12
" " ...	1 assayers' help	12
" " ...	1 blacksmith's help	10
" " ...	1 electrician	—
" " ...	1 bookkeeper	—
" " ...	1 assayer	—
" " ...	1 chief metallurgist	—
" " ...	½ chief mining engineer	—
" " ...	2 men and team hauling wood	—
Total ...	62½	

* It is assumed that 1 cord of wood is equal in effect to 1,000 lbs. of coal

The daily consumption of chemicals is as follows:—

				Per Ton of Ore.
				Lbs.
Copper sulphate	...	...	...	1·8 to 9·6
Sodium hyposulphite	...	...	...	1·5 to 7
Caustic soda	...	...	...	1·4 to 7·75
Sulphur...	...	...	...	0·9 to 5
Sulphuric acid	...	...	...	0·25 to 1·80

The water required is from 9 to 55 cubic feet per ton of ore, exclusive of that used for sluicing tailings.

The cost of wear and tear to cover all ordinary breakages, and wear and tear of machinery, boilers, screens, dry kilns, furnaces, lixiviation-plant, and refinery, including lubricants, electric light, and sundries, is about £7 5s. 10d. per day. For plants of small capacity the expenses per ton of ore, for labour, are, of course, materially increased. To the above must be added insurance, taxes, interest, legal expenses, etc., and amortization on the capital invested in the mill.

The total expenses at Cusi, Mexico, including refining, are said to have been £2 10s. 4d. per ton, using the Russel process.

For roasted ore at the Sierra Grande mill, Lake Valley, the total mill expenses for 60 tons per day were estimated by the general manager, Mr. Hadley, at 19s. 4d. per ton.

At Parral, Mexico, the total expenses for the treatment of tailings (from ore which had originally been roasted and lixivated by the ordinary process) were 8s. 9d. per ton for 40 tons per day. Treating roasted ores at the rate of 10 tons per day the total expenses were £1 18s. 1½d. per ton.

The cost of raw-leaching tailings at Silver Reef, Utah, treating 25 tons per day (the tailings assaying 6½ to 9½ ozs. of silver but no gold), is given by Mr. Egleston* as 6s. 10½d. per ton, the percentage extracted averaging 55 to 60 per cent. The presence of copper carbonate in these ores caused the sulphides to have a low percentage of silver (3,560 ozs. per ton) and a high tenour of copper.

Treating tailings from amalgamation-works at Silver City, concentrated up to 30 ozs. per ton silver, it is asserted that the Van Patera process only extracted 38 per cent. against 72·4 obtained by the Russel process.

Mr. Stetefeldt states that in a well-constructed lixiviation-mill the total expenses for treating 75 tons of raw ore per day should not exceed 12s. 6d. per ton, and under favourable circumstances should fall as low as 10s. 5d. per ton, particularly if the crushing were done by rolls instead of stamps.

* *Metallurgy of Silver*, page 532.

The chemicals required to be carried in stock for a lixiviation-plant of 80 tons daily capacity are estimated in an assumed case as amounting to about £878 0s. 2d., to last for 60 days, including sodium hyposulphite in stock solution.

Mr. Stetefeldt, page 213, says: "The Ontario mill expenses are about £2 14s. 2d.* per ton, those for lixiviation would be about £1 0s. 10d. to £1 5s. less, or a difference in favour of the Russel process of £1 0s. 10d. to £1 5s. in expenses, which, together with the additional extraction of 17s. 1½d., would make a total net difference of £1 17s. 6d. to £2 1s. 8d. per ton in favour of lixiviation."

As already remarked, however, in this the favourite instance taken for comparison of the two processes, the mill extraction by amalgamation is not nearly so high as it might be, and in the same way the cost, is nearly 12s. 6d. above the average of many amalgamation-works. Compare, for example, the expenses of mill B of the Granite Mountain Co. (43 stamps) for the year ending July 3rd, 1891, and it will be found that the milling charges did not exceed £2 4s. 8d. per dry ton, treating 19,463 tons dry, whilst in the case of the Elkhorn mill, which treated 11,645 tons, the cost was only £1 18s. 5½d.

If one compares the amount of labour required in a lixiviation and an ordinary amalgamation-mill in places where labour is dear, save in some exceptional cases, lixiviation must be the more costly process of the two, and it is in fact in countries like Mexico, where the conditions in this and other respects are favourable that it will find its widest adoption, until the labour costs common to all processes of the kind can be reduced considerably.

In confirmation of this statement the writer may cite the Geddes and Bertrand mill, Nevada† (an ordinary lixiviation-plant dealing with 50 to 60 tons per day), the staff of which, when running, consisted of 60 men, whose wages amounted to £30 6s. 3d. per day.‡ The cost of lixiviation milling (using rolls) came to £1 7s. 1d. per ton, and 13s. 8½d to £1 0s. 2d. in silver was still left in the tub-tailings.

Whilst leaching is doubtless applicable to certain ores in certain

* Mr. Egleston gives the actual running expenses, treating Ontario ore by amalgamation on a production of 50 tons per day as £3 2s. 7d., agreeing with Mr. Rothwell's figures. These works seem in fact to have employed an exceptionally large staff for a 40 stamp mill, viz., 66 to 72 men.

† The failure of amalgamation appears to have been due to the presence of antimoniate of lead in the ore.

‡ Egleston, "Leaching Gold and Silver Ores in the West." *Trans. Am. Inst. Min. Eng.*, vol. xii., page 40.

localities, it is always a process which involves highly skilled superintendence and chemical supervision, otherwise very serious losses may be incurred in roasting, leaching, and precipitating the metals, and in this way alone the possible profit to be gained by employing it may easily be converted into a positive loss.

TREATMENT OF THE SULPHIDES OBTAINED FROM THE RUSSEL PROCESS.

One of the great drawbacks of the Russel process which has been referred to, and which is common to other lixiviation processes yielding a base precipitate, viz., the treatment of the sulphides of lead, copper, iron, silver, and gold, produced by precipitation with alkaline sulphides, is now believed to have been overcome by a process invented by Mr. Cabell Whitehead. This new mode of treatment, it is stated, can be effected at a cost of $1\frac{1}{4}$ cents per ounce of contained silver, at the same time avoiding the frequent loss of silver that other methods entailed.

Refining on a cupellation hearth (the old method which is still in use in several mills) has the disadvantage of causing large losses of silver by volatilization in the previous roasting, and the locking up and eventual loss of a portion of the silver in slags, cupel-bottoms, and matte.

From 80 per cent. to 90 per cent. only of the silver charged was obtained in the shape of bars. The rest would be in greyish-black copper-lead silver matte, which would be formed early in the operation in the pasty slags which it was impossible to get rid of, and again the precious metals had a most pernicious faculty of sinking, not only into the cupel-bottoms, but below even into the iron-pan and into the surrounding brickwork. All these products had to be treated again, or shipped direct to a smelter. If they were shipped differences in assays, and possible losses were bound to occur, as the products contained shot silver. If the sulphides were charged upon the bath without undergoing a previous roasting under the mistaken idea of preventing the loss of silver by volatilization, the same troubles occurred in even a more pronounced degree. If the company shipped its sulphides direct to smelting or refining works, it avoided the great losses of this crude process, but incurred heavy expenses and discounts, amounting to as much as 10 per cent. on an average, in the case of a Mexican mine.

At present interest centres on two new processes, the one above alluded to, invented by Mr. Cabell Whitehead. This process is confined to the treatment of the sulphides as they are found in the precipitation tubs of a lixiviation plant. Its details have not yet been made public, but it is

stated that its success has been experimentally demonstrated, and the refining department of the Marsac mill of the Daly Mining Co., has been remodelled with a view to its adoption.

The other process aims to get at the root of the difficulty by precipitating electrolytically on zinc plates. Its success, whilst doubtful, must yet be proven before it is entitled to serious consideration.*

EXAMPLES OF THE RUSSEL PROCESS.

The careful preparation of the ore by a thorough chloridizing-roasting appears to be one of the chief points on which the success of the Russel process, in such cases as it may be applicable, turns. It does not appear to be adapted for the treatment of ores containing metallic silver, which is comparatively insoluble in cuprous hyposulphite. An account of the results of the process at two of the works where it has achieved its most successful results may be of interest.

For a description of its working at Las Yedras, Sinaloa, Mexico, the writer is indebted to an article in *The Engineering and Mining Journal*, New York, dated January 14th, 1893,† contributed by Mr. R. F. Letts. The Yedras mine of the Anglo-Mexican Mining Company is situated in the north-eastern corner of Sinaloa.

A 40 stamp mill and a lixiviation-plant to use the Patera or Kiss processes was erected in 1882. Poor results were obtained, and the Brückner furnaces which had been introduced were abandoned for the cruder but more satisfactory reverberatory, as the latter did not ball or agglomerate the roasted ore. It is estimated that the Patera process did not save over 65 per cent. of the silver in the roasted ore.

The following are two analyses of Yedras ore, representing the averages of the ore treated at different periods:—

	No. 1.	No. 2.
Carbonate of lime	33·78	46·50
Silica	15·13	25·00
Iron	17·33	9·80
Sulphur	13·31	12·50
Arsenic	9·82	2·50
Zinc	4·92	—
Lead... ..	1·78	—
Magnesia	2·58	—
Alumina	1·35	—

No. 1 is an analysis of the average battery sample for one month. The composition of the ore varies greatly. A couple of months later, analysis

* *The Engineering and Mining Journal*, New York, February 25th, 1893, page 169.

† Page 34.

No. 2 was made; the battery samples for several weeks showed 4 per cent. of zinc, and two months later contained a large percentage of antimony.

The results by using the Patera process were as follows:—Assay of ore, 60·67 ounces per ton; extraction in assay office, 72·09 per cent.; extraction in mill, 67·12 per cent.; total leaching time, 92 hours.

By the Russel process the results were as follows:—Assay of ore, 55·8 ounces per ton; extracted by old process in assay office, 69·94 per cent.; extracted by Russel process in assay office, 83·62 per cent.; extracted by Russel process in mill, 82·44 per cent.; leaching time, 76 hours.

It will thus be seen that the extraction by the Russel process was 15·32 per cent. higher than by the old process, and that the leaching time was 16 hours shorter. The chemicals consumed per ton of ore were as follows:—

				Old Process.		Russel Process.
				Lbs.		Lbs.
Lime	...	...	...	9·7	...	—
Sulphur	...	...	...	4·7	...	3·6
Hypsulphite of soda	...	...	...	—	...	1·4
Bluestone	...	...	...	—	...	9·6
Caustic soda	...	...	...	—	...	5·5
Total	...	...	...	14·4	...	20·1
Cost per ton	...	...	...	\$0·52 = 2s. 2d.	\$2·20 = 9s. 2d.	

Since these runs were made, the consumption of chemicals has been reduced to 9·14 lbs. per ton of ore and the cost to 0·82 dollars.

Owing to the great distance from the railroad, the price of chemicals in Yedras is of course considerably greater than at most places in the United States or at many localities in Mexico. The average cost of chemicals per lb. at Yedras for the last three years is as follows:—Hypo-sulphite of soda, 8 cents; bluestone, 10 cents; caustic soda, 9·1 cents; and sulphur, 7·1 cents. No soda ash (sodium carbonate) is used at Yedras as there is usually no lead in the ore. The total cost of all chemicals at Yedras in 1890 was 3·6 cents per ounce of silver produced. Of the copper used in the form of bluestone about 50 per cent. remains in the ore.

During the past five years the comparative efficiency of the two processes at the Yedras mill has been tested four times. The duration of each of these tests was from one to three months. Two methods were pursued in making these comparative runs. One was to divide the roasted ore equally between the two processes, running one-half the ore vats and precipitating-tanks on the old process and the other half by the Russel process, the products being kept entirely separate, and the tailings from each process thrown out.

By this method, however, there is a loss of 8 or 10 ounces per ton on all ore treated by the old leaching process, as that amount, which might be extracted by the Russel process if it were used on the same charges after the old process, remains in the tailings.

In the other method all the charges are treated first by the old process, that is, by the simple hyposulphite solution, until no more silver can be extracted, the sulphides being precipitated by themselves and kept separate. Then these same charges of ore are treated by the Russel process, that is, by cuprous hyposulphite or extra solution. The precipitates from this solution are likewise kept separate. In this way a comparison between the two processes is made without any loss, each charge of ore having the benefit of being treated by both processes before it is thrown out. In fact, this is the way all the ore is treated at Yedras, all charges being first treated by the old method, and then by the Russel process.

The first of the two comparative runs was made by Mr. Letts between the two processes in September, 1890 ; the test lasting a month.

An extract from his report to the Anglo-Mexican Company runs as follows :—"Our intention was to give the old process every possible show. Great care was taken to keep the precipitates separate, both at the beginning and end of the month. During the month no experiments or extra clean-up was carried out. In making the test we allowed the old process to take out all it could take, *i.e.*, we ran the vats (by the old process) so long as sodium sulphide would show the least trace of silver in the solution.

When the old process would not take any more silver out, the extra solution of the Russel process was applied, and, as in the case of the old process, was run as long as sodium sulphide showed any trace of silver."

The actual clean-ups from the two processes were as follows :—

	Ounces.
Extracted by the old leaching process	26,361·42
Additional extracted by the Russel process	5,088·76
Total produce	31,450·18
Per cent. of total produce extracted by old process ...	83·8
Per cent. of total produce extracted by Russel process	16·2

The total additional cost of the Russel process, or, in other words, the extra expense of producing 5,088·76 ounces over the cost of the old process was as follows :—Chemicals, 632·50 dollars ; fuel, 21·21 dollars ; extra help, etc., 155·60 dollars ; total, 809·31 dollars (£166 14s. 7½d.). At the then price of silver, the 5,088·76 ounces equalled 5,852·07 dollars. Deducting the above expenses 5,042·76 dollars (£1,050 11s. 6d.) is left as the net profit per month due to the extra treatment.

Another test was carried out during the month of November, 1890. In this run the total cost of chemicals per ton was 95 cents (3s. 11½d.). Of the total number of ounces extracted, the old process took out 80·29 per cent., and the Russel process the remaining 19·71 per cent. The additional ounces of silver extracted by the Russel process over the old process were 7,653·7, or (with silver at 1·025 dollars (4s. 3¼d.) per ounce) 7,845·04 dollars, making a net profit due to the use of the Russel system of about 7,000 dollars per month.

All the tailings which have been produced at the Yedras mill, by the old process before the introduction of the Russel process in 1887, have now been treated by the latter. The tailings are brought from the old dumps where they were thrown out in former years, and are charged direct to the leaching vats without any drying, roasting, or other treatment. Like the charges of ore, they are leached with water in order to remove the small percentage of soluble salts present; this washing requiring about four hours. A small percentage of ordinary hyposulphite solution is then applied, since the volume of the extra solution is only enough to saturate the charge, and as it would become diluted to some extent with the wash-water if it followed it, the small volume of ordinary solution is interposed.

As in treating ore, this extra solution amounts to 13 cubic feet per ton. It is followed by more of the hyposulphite solution to extract any silver which has been made soluble by the extra solution, but which has not passed out of the charge with it, remaining mechanically held in the pulp.

The total quantity of tailings from the old leaching process at Yedras, which have been re-treated by the Russel process, is between 30,000 to 40,000 tons. The following table shows the results:—

Year.		Ounces.		Extraction in Assay Office.				Apparent		Actual Extrac-	
				Old	Russel	Process.		Extraction	in Mill.	Process.	tion by Russel	Process.
				Per Cent.		Per Cent.		Per Cent.		Per Cent.	Per Cent.
1888	...	19·49	...	37·40	...	62·70	...	60·14	...	62·74	
1889	...	17·23	...	32·17	...	57·20	...	55·95	...	60·14	
1890	...	13·46	...	38·48	...	49·26	...	48·37	...	46·84	

In the above table, apparent extraction in mill is obtained by comparing the value of the final tailings from the Russel process with the old tailings, as charged to the leaching-vats (taking also into account any soluble salts).

Actual extraction in mill is obtained by comparing the clean-up in silver with the silver actually charged to the vats. The chemicals used per ton of ore during these three years were as follows:—

Year.	Hypo- sulphite. Lbs.	Blue- stone. Lbs.	Caustic Soda. Lbs.	Sulphur. Lbs.	Total Chemicals per Ton. Lbs.	Cost of Chemicals per Ton. Dollars. s. d.	Ounces of Silver Extracted per Ton.
1888 ...	2.08 ...	6.32 ...	5.54 ...	3.30 ...	16.24 ...	1.45 6 0½ ...	12.23
1889 ...	1.62 ...	5.11 ...	3.13 ...	2.69 ...	12.55 ...	1.12 4 8 ...	9.75
1890 ...	1.07 ...	4.06 ...	2.48 ...	1.71 ...	9.32 ...	0.82 3 5 ...	6.30

For a description of the Russel process at the Marsac mill, Park City, Utah, the writer is indebted to an article by Mr. W. G. Lamb in *The Engineering and Mining Journal*, New York, of December 17th, 1892.* It was started at these works on January 1st, 1889, superseding amalgamation at the end of that year. The statistics of amalgamation to which reference is made are from the Ontario mill in the same camp.

In that mill, amalgamation has been in continuous use since its start in January, 1887. As the wages and prices of fuel and supplies are the same for the two mills, a comparison of statistics is of value in determining the general efficiency and economy of the two processes, dealing, it should be added, with the same classes of ore, as the accompanying analyses indicate. The properties of the two companies, the Ontario and Daly, adjoin, and are in fact on the same vein. The equipment of the two mills and the staff employed are as follows:—Ontario, 2 rock-breakers, 2 rotatory driers, 40 ore-stamps, 10 salt-stamps, 2 Stetefeldt furnaces, 24 pans, 12 settlers, 71 mill men. Marsac, 1 rock-breaker, 2 rotatory driers, 30 ore-stamps, 5 salt-stamps, 1 Stetefeldt furnace, 6 (16½ feet) ore-vats, 8 (9 feet) precipitating-tanks, 51 mill men.

In the above connexion it is to be noted as before remarked that the labour item compared with figures given elsewhere appears unusually high at the Ontario for a 40 stamp amalgamating-battery, and correspondingly low for a lixiviation-plant of the same size, if the whole of the staff be included in both.

The analyses and values of the ore treated at the Ontario and Marsac mills for 1891 are as follows (the samples on which these analyses were made being composed of all the battery samples taken each day during the entire year):—

	Ontario.	Marsac
Silica ...	75.0 ...	76.60 ...
Zinc ...	5.73 ...	5.30 ...
Lead ...	1.80 ...	3.50
Iron ...	2.80 ...	1.65
Sulphur ...	2.23 ...	0.70
Lime ...	1.76 ...	1.32
Magnesia ...	0.23 ...	trace.
Copper ...	0.29 ...	0.39
Silver (ounces)...	39.50 ...	39.10
Gold (ounces) ...	0.044 (\$0.91) ...	0.044 (\$0.91 = 3s. 9½d.)

* Page 580.

The following table gives the crushing statistics for 1891 :—

MILL.	Ore.		Time Battery run.		Mesh of Screen.	Rate of Crushing per Day.		Rate of Crushing per Stamp, per Day.
	Tons.	...	Days.	...		Tons.	...	
Ontario (40 stamps)...	25,650	...	341·8	...	26	75·0	...	1·87
Marsac (30 stamps)...	24,214	...	347·0	...	20	70·0	...	2·33

The above difference in rate of crushing per stamp is probably not due entirely to difference in mesh of screen, for Ontario ore may not crush so fast as Daly, even in the same battery and with the same mesh of screen. Here again we have a matter which may affect the relative results (supposing one process replacing the other) in regard to cost.

The Ontario product in bars of bullion averaged 425 fine in silver and 0·250 fine in gold; it contained also 57·5 per cent. copper. The Daly precipitates, including those from the wash-water, but not the lead carbonate product, averaged 313 fine in silver and 0·260 fine in gold; they contained 15·3 per cent. copper.

The cost of marketing the product was 3·47 cents per ounce for Ontario bullion and 3·45 cents per ounce for Marsac sulphides. The price obtained was 97·55 cents per ounce for silver in Ontario bullion and 97 cents for that in Marsac sulphides. In the Marsac sulphides shipped, 20·67 cents per ounce was received for the contained gold, against nothing for that contained in Ontario bullion.

The following is the consumption of water, chemicals, iron, and power per ton of ore at the Ontario and Marsac mills :—

MILL.	Water.		Chemicals and Mercury.		Iron.	Power.*		Machinery Expenses.
	Cubic Feet.	...	Cost. Dollars.	...		Horse-power.	...	
Ontario ...	400	...	1·315	...	5·5	108	...	0·31
Marsac ...	56	...	0·924	...	0·05	8	...	0·07

The consumption of chemicals has increased since 1890 owing to the adoption of hot-solutions. The production increased 2·8 per cent. however, and while the total cost was increased 7,339·98 dollars the net gain in extraction after deducting the extra cost amounted to 18,478·92 dollars.

The following are some additional details of work at the Marsac and Ontario mills in 1891, when the 30 stamp Marsac mill crushed 24,215 tons of ore through a 20 mesh screen against 25,650 tons through a 26 mesh screen at the 40 stamp Ontario mill :—

MILL.	Fuel.		Salt used in Roasting.		Labour.†	Extraction of Silver.	
	Per Ton. Dollars.	...	Per Cent.	...		Per Cent.	...
Ontario (cords of wood) ...	0·153	...	13·9	...	0·46	...	90·8
Marsac (tons of coal) ...	0·087	...	8·26	...	0·31	...	91·8

* This is for power for driving pans and settlers at the Ontario, and for stirring and handling solution and grinding sulphides at Marsac.

† Includes that on the pans, amalgam, and bullion at Ontario; and on vats and shipment of sulphides at Marsac.

During 1892, up to December 1st, the percentage of salt used at Ontario had been increased to 14·2 per cent., and that at Marsac 9·5 per cent. The extraction at the Ontario mill remained at 90·8 per cent., and that at the Marsac 91·9 per cent. It is probable that the extraction at the latter works would be increased if the cooling floor-space were enlarged, so as to allow the ore to cool without wetting down. This would increase the expense, it is estimated, by only 13 cents per ton.

The following is the detailed annual cost of the lixiviation department at the Marsac mill:—

		Dollars.		Dollars.	s.	d.
Labour—						
1 foreman,	\$5·00;	3 leachers,	\$4·00;	3		
shovellers,	\$3·00;	1 pressman,	\$3·50;			
1 labourer,	\$1·50	...	...	16,790·00	...	0·6934 = 2 10½
Chemicals—						
		Dollars.	Dollars.			
Hyposulphite	...	152,808 lbs. at ·0362	= 5,531·64			
Bluestone	...	78,569 lbs. at ·0641	= 5,036·27			
Caustic	...	119,741 lbs. at ·0555	= 6,645·62			
Sulphur	...	80,486 lbs. at ·0257	= 2,068·49			
Soda ash	...	22,309 lbs. at ·0317	= 707·19			
				19,989·00	...	0·8255 = 3 5½
Repairs—						
1 machinist,	\$4·00;	materials and supplies,				
\$2·50 per day	...	...	...	2,372·50	...	0·0979 = 0 4½
Power	...	...	...	3,139·89	...	0·1297 = 0 6½
Assay office	...	...	...	2,008·82	...	0·0830 = 0 4½
Total cost	...	...	...	\$44,350·21	...	\$1·8295 = 7 7½

Figures for the following comparison of the Ontario and Marsac results for 1891 are taken from the respective reports of the Ontario and Daly mining companies:—

		Dollars.		Dollars.		£	s.	d.
Ontario—								
Cost of milling per ton	...	...	8·93					
Product expense	...	...	1·23					
				10·16	=	2	2	4
Marsac—								
Cost of milling per ton	...	...	6·27					
Product expense	...	...	1·23½					
				7·50½	=	1	11	3
Difference in favour of Marsac	...	...	...	2·66	=	0	11	1
Ontario—Mill extraction	...	...	91·00 %					
Marsac	...	...	91·57 "					
Difference in favour of Marsac	...	...	0·57 "	=	0·21½	=	0	0 10½
Ontario—Realized from gold	...	...	0·00					
Marsac	...	...	0·63½					
Difference in favour of Marsac	...	...		0·63½	=	0	0	7½
Total difference claimed in favour of Russel process	...	...		3·51	=	0	14	7½

This total difference of 3·51 dollars would, it is asserted, have made a saving of 91,057 dollars, had the Ontario ore, amounting to 25,650 tons in 1891, been treated by the Russel process. Mr. Lamb sums up by saying that to treat about the same number of tons of ore per day, of approximately the same composition at the Marsac mill, the Ontario mill requires 39 per cent. more labour, 30 per cent. more stamps, more power, twice the number of furnaces, 48 per cent. more salt, and 40 per cent. greater cost of chemicals, and yields a smaller percentage of both gold and silver than the Marsac mill using the Russel process.

Whilst this may be true, a slight difference in the composition of the ore may affect the extraction, and looking at the respective analyses given, it seems hardly fair to assume that, even in the case of Ontario and Marsac ores, the commercial results of the lixiviation treatment will be exactly the same in both cases.

A comparison of extraction by lixiviation (using the Russel process) with that by amalgamation made in 1891 at the new works of the Blue Bird mine, Montana,* showed that the extraction by amalgamation varied from 58·5 per cent. to 80 per cent., while with lixiviation it averaged 84·1 per cent. It is claimed that the extraction might have been 8 per cent. higher (judging from experience elsewhere) if the lixiviation charges had not been wetted down hot.

The analysis of the battery samples for six months showed the ore to contain :—

						Per Cent.
Silica	...	...	...	...	...	61·4
Sulphur	...	...	...	...	...	5·0
Iron	...	...	...	...	...	3·74
Lead	...	...	...	...	...	4·22
Zinc	...	...	...	...	...	12·8
Manganese	...	...	...	...	...	5·21
Copper	...	...	...	...	...	0·20

The cost of chemicals and quicksilver averaged 0·80 dollars for amalgamation and 0·99 for lixiviation, using 3·3 to 3·7 lbs. of hypo-sulphite of soda, 5·6 to 9 lbs. of bluestone, 3·7 to 6·7 lbs. of soda ash, 4·4 to 5 lbs. of caustic soda, and 2·5 to 3·4 lbs. of sulphur, making a total of 18·8 to 27·5 lbs. of chemicals per ton of ore treated.

The leaching vats were filled with 20 to 70 tons charges about 7½ feet deep. The first part of the wash-water was run in from below the filter, while the ore was being charged into the vat, the leaching with water being afterwards introduced from below downwards as soon as the ore

* C. A. Hoyt, *The Engineering and Mining Journal*, New York, Jan. 7th, 1893, page 8.

was charged. The base-metal leaching was followed by about 100 inches in depth of ordinary solution. This was succeeded by about 30 inches of extra solution, containing 1 per cent. of bluestone, which was allowed to stand seven to ten hours. This was again followed by 40 to 60 inches of ordinary solution, and then by 10 inches of extra solution of the same strength as before, which was allowed to stand seven to ten hours, and finally 50 to 60 inches of ordinary solution was run in and was expelled by the second wash-water.

The strength of the stock solution was 1·6 per cent. to 1·9 per cent. of hyposulphite of soda, whilst the extra solution contained in addition 1 per cent. of bluestone.

All solutions were kept at a temperature of 90 to 120 degs. Fahr., 11 to 15 per cent. of salt was used in roasting, and the ore was crushed on the average to pass a 24 mesh screen, the salt to 20 mesh.

The silver and gold were precipitated from both solutions and wash-water with sodium sulphide; and the lead by itself from the solutions by soda-ash.

Mr. H. Lang, in a letter to *The Engineering and Mining Journal*,* New York, of March 18th, 1893, remarks:—"The Russel Company summarizing their claims declare that the Russel process, both metallurgically and economically, occupies the place formerly held by:—1st, the Kiss-patera, or old leaching process; 2nd, amalgamation of silver and silver-gold ores; 3rd, smelting of dry ores, and ores averaging not over 15 per cent. lead, or such as do not contain sufficient lime or iron to make them desirable as fluxes in smelting."

Without expressing an opinion on the merits of the first two claims, Mr. Lang takes emphatic exception to the third and says:—"In no case and under no conditions can the Russel process treat basic ores as cheaply or as efficiently as can the smelting processes. With acid ores I recognize in full its advantages, but even with the most siliceous material it is questionable if the process can always compete with matting, even when silver alone is treated; and when gold, copper, and other metals are worked for, it has no chance whatever."

In 1889, a company of Oregon capitalists erected a rather complete Russel process mill at Mineral, Idaho (a quarter of a mile below the spot where a matting plant now stands) at a cost of £6,250, which was under the charge of a skilful leaching-expert, Mr. W. H. Lamb.

Mr. Lamb laboured arduously and intelligently through several months; but, in vain, the project was a failure, and the mill was shut down and sold for a tenth of its cost for other purposes.

* Page 244.

According to Mr. Lang's information, the best results reached 76 per cent., though it does not appear whether this was the extraction, apparent extraction, or simply an extra extraction. He goes on to add that the ores in question (of which only the more tractable part were sought to be worked in the Russel mill) have been bought by his firm during the last three years, and successfully treated in matting furnaces. That they have made it pay where the Russel process failed, is a sufficient answer to the assertion that the process occupies the place of smelting.

Treating the same ores, he claims to be able to do the work at one-fifth the cost, and save 20 per cent. more silver than the Russel process claimed to extract.

The high cost of treatment at these works is stated, however, to have arisen largely from faults of construction and design.

The claims of the process for the treatment of basic ores are only relatively true. The Russel Company quote an analysis of the Las Yedras ore (Sinaloa, Mexico) and say "smelting being economically and *metallurgically** out of the question." (This was said of an ore containing silica, 25 per cent.; calcite, 46 per cent.; iron, 9·8 per cent.; sulphur, 12·5 per cent.; and arsenic, 2·5 per cent.) Instead of being an unsmeltable combination, this ore is in reality the finest smelting product in the world, susceptible of being run down at one operation into a high-grade matte, and at less than the cost of the salt which is now used in roasting. And the matte can then be refined, and its total silver extracted at an additional cost per ton of original ore, not exceeding the cost of the chemicals now used in the Russel leaching. Mr. Lang bases this opinion on the data given in the valuable series of papers by Mr. Rockwell, published in *The Engineering and Mining Journal*,† New York, "On Roasting, Chloridizing, and Lixiviation at Yedras mine, Mexico." The Yedras ore is chemically nearly the same as that of an important mine near Mineral Hill, of which considerable quantities have been treated by Mr. Lang's firm, the difference being an excess of carbonate of lime in the Mexican ore. This is run down without the use of fluxes and without admixture of other ore, using 7 per cent. of coke.

Employing a furnace of special construction and by peculiar treatment of the blast, etc, the larger part of the sulphur and arsenic is burnt off, and the corresponding proportion of iron and zinc is slagged off, effecting a desirable concentration of the matte and at the same time utilizing the heat of combustion of the elements named. This is pyritic smelting, properly so-called, a branch of the larger art of matte smelting

* The italics are mine. † Vol. xlv., pages 86, 106, 159, 178, 197, 213, and 283.

The waste of silver at Las Yedras must have been prodigious. Mr. Rockwell mentions months of work in which the losses by volatilization varied from 17 to 25 per cent., the best work attainable in his time resulting in an average loss of 10 per cent. from that cause. The Russel company have recorded it at 6 or 7 per cent. The total losses now amount to about 19 per cent.

The Russel process has undoubtedly been a great improvement over the old leaching with certain classes of ore, but it is a great wonder that the management tolerated any lixiviation methods whatever.

Mr. Lang states that he holds the same opinion concerning the Aspen* and Marsac works. The composition of the Aspen ore (30,000 tons of which have been treated by the Russel process) is lead, 2·27 per cent.; silica, 21·66 per cent.; sulphate of barium, 20·92 per cent.; lime, 10·99 per cent.; magnesia, 4·24 per cent.; iron, 10·02 per cent.; zinc, 2·85 per cent.; copper, 16 per cent.; sulphur, 8·10 per cent.; and arsenic, traces.

* The probable cost of pyritic smelting in this district would be under 12s. 6d. per ton, treating not less than 100 tons per day.

**CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION
OF ENGINEERS.**

GENERAL MEETING,

HELD IN THE ROYAL VICTORIA STATION HOTEL, SHEFFIELD, APRIL 8TH, 1893.

MR. HENRY LEWIS, PRESIDENT, IN THE CHAIR.

The SECRETARY announced the election of the following gentlemen :—

MEMBERS—

- Mr. FRED CHAMBERS, Assistant Manager, Birley Collieries, Sheffield.
Mr. ARTHUR STANLEY DOUGLAS, Mining Engineer, Hucknall Torkard, Nottingham.
Mr. WILLIAM ELLIOTT, Manager, Blackwell Collieries, Alfreton.
Mr. JOHN GRINHAF, Under Manager, Swadlincote Old Colliery, Burton-on-Trent.
Mr. WALFORD HUNT, Colliery Manager, Haunchwood Brick and Tile Co., Limited, Nuneaton.
Mr. JOHN FORSTER LEE, Colliery Manager, Sheepbridge Ironworks, Chesterfield.
Mr. GEORGE WATSON MACALPINE, Colliery Proprietor, Altham and Great Harwood Collieries, Accrington.
Mr. JAMES MEIN, Colliery Manager, South Normanton Colliery, Alfreton.
Mr. JACOB PEARCE, Colliery Manager, Boythorpe Collieries, Chesterfield.
Mr. HENRY STOKER, Mining Engineer, and Lecturer to the County Council of Nottingham, 5, Argyll Mount, Mansfield.
Mr. SAMUEL WHEATLEY, Colliery Manager, Nailstone Colliery, Leicestershire.

ASSOCIATE MEMBERS—

- Mr. TOM WILSON AUSTIN, Colliery Deputy, Grassmoor, Chesterfield.
Mr. GEORGE BALL, Deputy, B Winning, Blackwell Collieries, Alfreton.
Mr. HENRY BLAIR, Under Manager, Alma Terrace, Brampton, Chesterfield.
Mr. AARON BOOTH, Under Manager, B Winning, Blackwell Collieries, Alfreton.
Mr. JOHN HENSHAW, Under Manager, Butterley Park, Alfreton.
Mr. WALTER HOLLAND, Under Manager, Brampton Colliery, Chesterfield.
Mr. HERBERT KNIGHTON, Under Manager, High Park Colliery, Greasley, Nottingham.

Mr. THOMAS MACHIN, Under Manager, Blackwell, Alferton.
Mr. BENJAMIN MORRIS, Deputy, Blackwell Collieries, Alferton.
Mr. JOHN OSBORNE, Deputy, Blackwell Collieries, Alferton.
Mr. CHARLES PERCIVAL, Deputy, Linton, Burton-on-Trent.
Mr. JOSEPH PERCIVAL, Under Manager, Netherseal Colliery, Burton-on-Trent.
Mr. WILLIAM ARTHUR PUGHE, Surveyor, Butterley Park, Alferton.
Mr. THOMAS SEVERN, Under Manager, Clifton Colliery, Nottingham.
Mr. CHARLES WILDEES, Deputy, Blackwell Collieries, Alferton.
Mr. RICHARD WOODS, Surveyor, Jessop Street, Codnor, Derby.

STUDENTS—

Mr. ROBERT OWEN DE KINGSLEY HALL, Mining Surveyor, Treeton, Rotherham.
Mr. JOHN WILLIAM LYON, Mining Student, The Firs, Annesley, Nottingham.
Mr. FREDERICK WILLIAM PAGE, Mining Student, Blackwell Collieries, Alferton.
Mr. ISAAC SAXTON, Mining Student, Hasland, Chesterfield.
Mr. HORACE WILKINSON, Mining Student, Blackwell Collieries, Alferton.

ALTERATION OF RULES.

The **PRESIDENT**, on behalf of the Council and agreeably with the terms of the agenda-paper for the meeting, gave notice as follows:—"The Council of the Federated Institution of Mining Engineers having, in accordance with their Bye-law 8A, desired all the Federated Institutes to revise their rules, in order that the members shall consist of Ordinary Members, Associate Members, and Honorary Members, with Associates and Students, and to adopt the model Bye-law 8B (see the second page of Federated Institution Bye-laws), a resolution to modify the existing rules accordingly, to take effect from the commencement of the current year, will be brought forward for discussion and determination at the Annual Meeting on July 1st next, in Chesterfield."

NOMINATIONS FOR ELECTION OF OFFICERS.

The **CHAIRMAN** said the Council were of opinion that there should be only one nomination for the office of President, and he had very great pleasure in announcing the nomination of **Mr. Alfred Barnes**, who had kindly consented to stand for appointment for the ensuing year. He was sure he was only expressing the opinion of the whole of the members of

the Institution when he thanked Mr. Barnes for accepting the presidency. Undoubtedly his great knowledge of the coal and iron trades would be of very great value to that Institution.

The SECRETARY announced the following names of members who had been selected by the Council for formal nomination at this meeting, viz. :— Vice-Presidents : Messrs. S. Alsop, M. Deacon, C. H. Oakes, and J. B. Smith, eligible for re-election ; and in addition, Messrs. W. D. Holford, M. H. Mills, C. S. Smith, W. Spencer, H. Walters, and W. Wilde ; Councillors : Messrs. A. G. Barnes, G. J. Binns, C. P. Markham, W. Salmond, T. A. Southern, and W. E. Wells, eligible for re-election ; and in addition, Messrs. G. S. Bragge, P. M. Chester, J. Dutton, H. R. Hewitt, J. Humble, C. R. Morgan, R. H. Robinson, W. H. Sankey, R. J. Strick, R. Thornehill, and M. Wolstenholme.

The CHAIRMAN asked if there were any further nominations, and none being made, the above were approved for ballot.

Mr. ALFRED BARNES said he was much obliged to them for having nominated him to the post of President of that Institution, although personally he would have preferred to be untrammelled by the burdens of office. At the same time, he was desirous of doing as much as he could to further the interests of the trade in which such a large number of them were interested. A very unsettled time was coming upon them, and considerable difficulties would have to be faced. They were aware that his knowledge, so far as the management of a colliery was concerned, was not now connected with the details of management. That had been out of his hands for some time, and members therefore must not expect any knowledge of that sort ; but, so far as the parliamentary part and the commercial part of it were concerned, his forty-five years' experience might be of some advantage to them. It might interest some of them to have some information on the official report of the Mining Royalties Commission. He had got a great deal of information on the subject. The report and five volumes of very valuable evidence would probably be out in ten days, and then could be purchased by the public. As it gave information of the royalties, etc., in all the countries in the world, he thought every person connected with a colliery ought to read it.

REPRESENTATIVES ON THE COUNCIL OF THE FEDERATED
INSTITUTION OF MINING ENGINEERS.

The re-nomination of the present representatives was agreed to, viz., Messrs. G. Lewis, J. Jackson, J. A. Longden, H. Lewis, G. E. Coke, M. H. Mills, and W. Spencer, with the further nomination of Mr. A. Barnes, in the event of a vacancy, or in case the increased number of members in the Institution should warrant an additional representative.

The meeting then closed.

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION
OF ENGINEERS, AND MIDLAND INSTITUTE OF MIN-
ING, CIVIL, AND MECHANICAL ENGINEERS.

JOINT MEETING,

HELD AT THE ROYAL VICTORIA HOTEL, SHEFFIELD, APRIL 8TH, 1893.

MR. W. E. GARFORTH IN THE CHAIR.

The CHAIRMAN said the principal object of the joint meeting was to visit collieries in the district, but it was also satisfactory to meet together and discuss certain matters which were brought before them. The members of the Institutes must be pleased to see year after year these meetings increase in number and importance. They were told at Derby a few weeks ago that the Federated Institution of Mining Engineers was growing; and they might look forward to the time when they should be worthy of a Royal Charter. He thought it was most essential that the *Transactions* should be good, and that all matters connected with mining should be brought before them from the various mining districts through the Federated Institution of Mining Engineers. They encountered the difficulties connected with increased depths, and when they remembered that coal had been already worked at a depth of 1,000 yards, and that in the future it would be worked at much greater depths, he thought they ought to take advantage of every opportunity of obtaining scientific information. This could be advantageously effected by each district recording its facts which, though perhaps little in themselves, would, when added together, greatly assist in the education of mining engineers. This was the third occasion of a meeting at Sheffield, and he trusted that similar reunions would continue to be held annually of the members of the neighbouring institutes.

Mr. W. HOOLE CHAMBERS read the following paper on the "Arrangements for Sinking to the Whinmoor Seam from the Silkstone Seam at the Tankersley Collieries":—

ARRANGEMENTS FOR SINKING TO THE WHINMOOR SEAM FROM THE SILKSTONE SEAM AT THE TANKERSLEY COLLIERIES.

BY W. HOOLE CHAMBERS.

On the approaching exhaustion and diminution of the output from the seams which have been worked at the Tankersley collieries for about thirty years, it was decided to utilize the existing plant for working the Whinmoor seam. It was accordingly determined to sink the No. 1 shaft, which had already won the Silkstone seam at a depth of 519 feet, down to the seam below, a further depth of about 180 feet. In order to do this successfully, it was necessary to provide that during the drawing of coal from the Silkstone seam in the day-shift, the shaft at the Silkstone bottom was properly and effectually covered over. Further, it was desirable that whatever was used for this object, was not only substantial and strong, for the cage lighting upon it, but also that it could be rapidly and expeditiously removed and allow of the sinking operations being commenced immediately after coal-drawing was done and the men of the first shift in the Silkstone seam were out of the pit.

The No. 1 shaft is 12 feet in diameter. The conductors are of wood, 4 inches wide by $4\frac{1}{2}$ inches deep, fitted at each end of the cage: these cease at the top and bottom of the shaft, and in their place four oftakes or guides are placed, one at each corner of the cage, to enable the full and empty tubs to enter and leave the cage at the end. The full corves are put on at the basset side of the shaft A (Fig 1, Plate XI.). In order to provide a lorry for covering the shaft during sinking operations, two beams, 12 inches square, were placed at the top and low side of the pit and let into the brickwork at either side. Above these were inserted the beams for the lorry to run on, 18 feet long and 8 inches square, projecting on the low or dip side of the pit, the ground being taken out for the purpose. This excavation was made opposite the north-side cage, and measured 8 feet 7 inches by 6 feet by 2 feet 6 inches. These beams are $4\frac{3}{4}$ feet apart; the rails for the lorry are fixed upon them. The rail-gauge is 5 feet $2\frac{1}{4}$ inches. The lorry is of ordinary construction, and its top is covered with metal flags, and is of such a height that when run back from the shaft it is exactly level with the regular pit-bottom flags, consequently it answers for and occupies the position of the ordinary flags for the empty corves from the north-side cage to pass over when drawing coal. When

the lorry is drawn back from the shaft it is kept in position by the beam E, and also by a catch, so that it is impossible for it to move forward.

Fig. 2, Plate XI., shows a section taken across the centre of the shaft looking east towards the dip side, when the lorry is run back from the shaft and the shaft ready for drawing coal. E is the timber at the eastern or low side of the pit upon which the other removable timbers rest. It is notched to receive the rails, and also slightly notched to go a little below the main timbers in the centre. It is carried when in position by the timbers F F. B B are the timbers on which the cage rests when at the bottom of the pit; they are fitted with spikes, firmly fastened to them with a collar underneath and a nut at the top, at each end to fit into the timbers below them, and serve to keep the timber E from moving out of its place. Those at the basset side are firm and immovable. When the cage is at rest on these timbers, its bottom is level with the top of the lorry. The timbers to be removed in order to commence sinking are A, B, C, D, and E, the others remaining fixed.

In order to allow for the passage of the lorry it was necessary to provide for the removal of three of the offtakes, or substituted guides at the eastern or dip side of the pit. For the purpose of keeping the top-ring of the cage in the offtakes, joints G were inserted (Fig. 2), the bolts of these joints being taken out when needful. The bottom of these loose removable pieces were in each case let into iron sockets, so as to render them perfectly firm when drawing the coal. Fig. 3, Plate XI., is a plan of the shaft-bottom at the Silkstone seam when covered over.

In order to avoid any strain whatever on the cage by the weight of any material drawn from the sinking-shaft a large shackle (Figs. 4 and 5, Plate XI.) was inserted in the large ring which carries the two centre chains of the cage and between them. Two large links of $1\frac{1}{2}$ inches iron (4 inches inside) made the connexion with two chains of $\frac{5}{8}$ inch iron, which pass down through the bonnet of the cage on each side of the central hoop of the bonnet, and remain permanently fixed on the cage. A hole large enough to admit the end of the sinking-rope is made in the bottom of the cage. When the sinking-rope is required, it is brought up and passed through the bottom of the cage, a large shackle of $1\frac{1}{2}$ inches to $1\frac{3}{4}$ inches iron is inserted through the two chains, the pin (of $1\frac{1}{2}$ inches iron) is passed through the capped-end of the rope, the cotter inserted, and the attachment is complete. The travelling road to the dip portion of the workings goes down immediately opposite the shaft, and during the day-shift the rope is left hung on supports fixed in it for the purpose.

The ordinary bell-signal was used when drawing coal, and an electric signal was alone adopted when sinking.

When commencing to prepare for sinking, after the electric signal was tested, the north-side cage was raised about 3 feet from the bottom. The rope was then brought by hand and attached through the bottom of the cage to the chains. The rope was then drawn up by the engine until the whole 70 yards was hung in the shaft. The timbers and boards were then lifted by the engine and swung into the top-side porch in the following order:—C, B, B, A, D, and E.

While this was being done, other men had taken out the offtakes from the sockets into which they fit. The trunk, which was standing in one of the side-porches, was brought on to the lorry and run over the pit and attached to the rope.

The usual time occupied by these operations was six and a half minutes. As the rope under the cage had not been in use during the day-shift, it was necessarily tested in the usual way. This and the needful change to an empty trunk occupied a further time of four minutes. Everything was ready in ten and a half minutes for the examination of the shaft being made, prior to the descent of the sinkers to their work.

The trunks were constructed to hold one corf of the material from the sinking—they were swivel-trunks, tipping over on their centre, and when in use an empty corf was placed on the lorry which was run over the shaft, and the trunk tipped into it. These corves were stored along the shaft-levels and either drawn out amongst the coals in the day-shift, or taken down into the workings and the stone used for packing.

The lorry was constructed so as to cover the whole portion of the shaft occupied by the timbers removed, and there was no possibility of any dirt, which might accidentally run over the sides of the corf placed for its reception, falling down upon the sinkers. As the lorry completely covered the space occupied by the timbers, it was unnecessary to replace the timbers when changing the men of the second and third shifts between 9.30 and 10 p.m. The only operation necessary, after the sinkers had ascended to the Silkstone seam, was to remove the rope, and the lorry, being pushed over the pit, acted as a floor for the north-side chair to rest upon; although somewhat higher than the other cage it was perfectly safe.

Figs. 6, 7, and 8 show the hopper, which was arranged below the Silkstone seam to prevent the trunk from catching the beams F F when drawing material. Fig. 6 is a plan of the shaft at the bottom of the hopper, which was 6 feet 4 inches by 7 feet 10 inches at the bottom and 4 feet 9 inches by 5 feet 8 inches at the top. The timbers across the shaft at this point are 7 inches by 3 inches, and $\frac{3}{4}$ inch boards are used for the sides of the hopper.

FIG. 4.



FIG. 5.

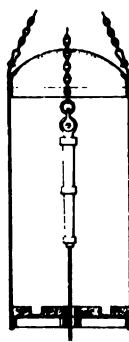
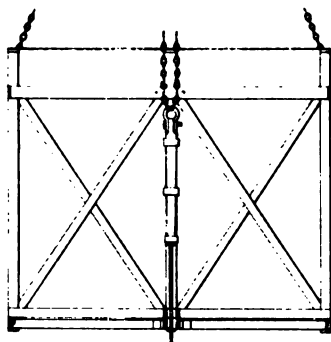
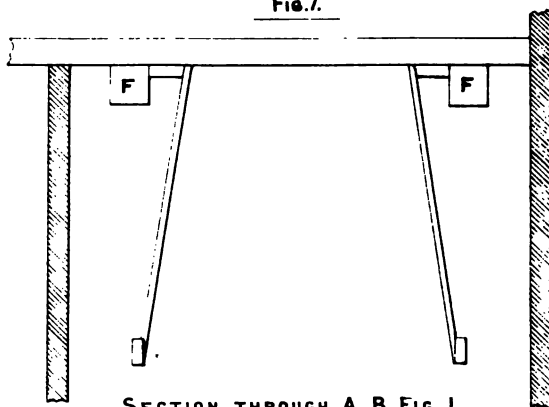
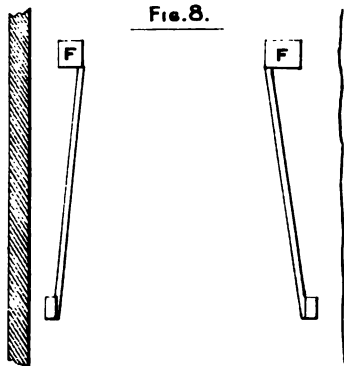


FIG. 7.



SECTION THROUGH A B FIG. 1.

FIG. 8.



SECTION THROUGH C D FIG. 1.

100

100

By the means detailed, the change from drawing coal to descending the sinking-pit was made in about ten and a half minutes, and the sinkers were at work in the bottom in a quarter of an hour. When it was necessary to send anyone out from the Silkstone seam on account of an accident, or when the time for changing shifts arrived, it only involved the removal of the rope for about five minutes. The importance of these speedy arrangements will be recognized, as the sinking operations could only be pursued from 4 p.m. until 6 a.m., and a portion of this time was wasted in changing shifts (of from 60 to 70 men) at about 10 p.m.

Mr. GEORGE LEWIS asked how long it took to sink to the depth of 100 yards, and whether any water had been met during the sinking?

Mr. W. HOOLE CHAMBERS said a little water came in from the low-level close to the sinking, but means were taken to prevent it going down the pit. From the first crib to the Silkstone bottom, the walling was cemented, and it was sufficient to prevent any water following down the pit. The depth was 60 yards, which was sunk at the rate of about 5 yards per week; during several weeks they sank 5 yards, and sometimes 4 yards. In making alterations, such as he had described in his paper, they had the difficulty of changing the men in the various shifts and to get ready for the examination of the ropes in the morning, so the time left for sinking was short.

Mr. HENRY LEWIS said none of the plans showed how the sinking pit was ventilated.

Mr. W. HOOLE CHAMBERS—No.

Mr. A. H. STOKES proposed a vote of thanks to Mr. Chambers for his paper.

Mr. HENRY LEWIS seconded the vote of thanks, which was carried unanimously.

Mr. T. W. H. MITCHELL read the following paper, contributed by Mr. Wm. Foulstone, of Barnsley, on "A Combined Centre-line Apparatus":—

A COMBINED CENTRE-LINE APPARATUS.

BY WILLIAM FOULSTONE.

During many years' experience in the sinking of pits, the writer found that difficulties and delays occurred in fixing the centre-lines of shafts in the ordinary manner, and with the object of obviating such occurrences he has constructed an apparatus which can be used for accurately putting on and preserving the centre-line in sinking deep shafts. His object is to use an accurate and permanent apparatus, whereby the accuracy of the centre-line can be tested as often as required without much labour and with little waste of time, and at the same time causing very little delay and inconvenience to the workmen employed in the shaft.

The apparatus (Figs. 1, 2, 3, and 4, Plate XII.) consists of a wrought-iron beam *a*, fitted at the end hanging over the sinking-shaft, with a pulley *b*, over which the centre-line *c* is passed. There is a rack *d* on the top of this beam by which it can be moved backwards and forwards between the two fixed girders *e, e*, which are supported over the pit-top by wooden beams *f* and *g*. The drum and gearing are fixed on the girders *e, e*. By this arrangement of the beam *a*, and of the drum and gearing, the centre-line can be moved up and down the shaft, either at the centre *b*, or at the sides of the shaft *h*. When the use of the centre-line is finished, the line with the weight is hoisted a few yards up the pit, the beam *a* is drawn back, and the centre-line is left hanging near one side of the pit *h*.

The advantages claimed for this apparatus over the old methods are :— (1) there is a considerable saving of time in putting on and taking off the centre-line ; (2) it is a permanent fixture, and more reliable and safer than loose tackle, which, under the old method, had to be fixed daily or nightly by the banksman over the pit-top when the men were working in the bottom.

When the winding-rope runs out of the centre of the shaft (this is frequently done, so as to provide for fixing pumps down one side) the centre-line can be lowered from its position (about 30 yards from the pit-

bottom) to the bottom, and then pushed forward from the side to the centre of the shaft, while the workmen are filling the hoppet or trunk. Under the old system, the centre-line spins for some time after the heavy weight is put on to straighten and steady it before use, and it has to be wound to the surface after use and the wooden bar and pulley removed. With the new apparatus, the centre-line is always hanging in the shaft with the weight on it, about 30 yards from the bottom, and spinning is entirely avoided.

When the winding-rope runs in the centre of the shaft, the centre-line can be lowered to the bottom, ready to be pushed forward to the centre of the pit as soon as the hoppet or trunk is raised above the surface to empty the *débris*, and, while this is being done, one man can push the line to the centre of the shaft and place it in the required position in a few seconds.

If this apparatus be placed in line with the centre of the winding-engine drum and the centre of the shaft, it will be found of great service in setting-out porches or arches in line with the surface-line with one centre-line. The centre of the pit is marked with the line, and another mark made when the line is drawn back to the side of the shaft; a line drawn through these points, projected will be the centre-line of the porches or arches. The sump-frames can also be set out in the same manner.

When sinking and when large quantities of water have to be laded for a short time to save putting in pumps, the use of the centre-line is very often neglected on account of the time wasted by the old method. Where the water accumulates quickly in the shaft-bottom, it often takes two or three hours to lade the water out again, and if the use of the line be neglected, it is usual in such cases to sink the shaft of larger diameter, so as to ensure its being of the required size. All this extra space must be filled with brickwork or *débris* (when the pit is walled) from the surface at extra expense. In such cases with the combined centre-line apparatus, the line can be placed in so short a time that it will be frequently used; the chargeman of each shift can ascertain for himself the state of the shaft in a few minutes before commencing work, and save all unnecessary labour; and the cost of the apparatus will probably be saved in a few months. The centre-line can be put on with this apparatus as quickly at a depth of 700 yards as at 50 yards; and the apparatus will be found most advantageous in the case of the deeper shafts.

Mr. HENRY LEWIS asked the cost of the apparatus? In his experience of sinkings, which had been considerable, the centre-line was only used when putting in curbs at intervals of three or four weeks. The centre-line was used for every curb, but the side-line was considered to be a sufficient guide for the excavation of the shaft. Unless the arrangement was very cheap, he did not think there would be much saved by having that centre-line constantly hanging in the shaft.

Mr. FOULSTONE said the apparatus cost about £36, and after twenty-five years' practical experience he found its use to be most advantageous. Pits were sunk by side-lines from curbs, but the curbs were not always placed true. It was the rule to put in curbs from the centre-line, and to sink between them by side-lines, but he had known curbs $\frac{3}{8}$ inch out of a circle. If they trusted to curbs they might not always get an accurately circular shaft. There was no better system than working to one true centre-line.

Mr. HENRY LEWIS remarked that no curb should be set with a side-line.

Mr. FOULSTONE said that every time a shot was fired some of the side-lines could be cut. The centre-line was the best method for use in sinking. With side-lines too much might be taken off the side. There were many pits which were not plumb from top to bottom.

Mr. HENRY LEWIS said there was always a tendency to take more ground out than was necessary.

Prof. ARNOLD LUPTON asked how long it took to steady the centre-line when 700 yards long?

Mr. FOULSTONE said it would take ten minutes to steady the line to a depth of 700 yards with his apparatus; whereas he had known pits sunk with the old system where it had taken more than an hour to steady the line. With his apparatus the weight was always on the line some 20 yards above where the men were working, and when it was lowered to the bottom there was no heavy swag upon it, and it became steady directly.

Mr. HENRY LEWIS asked what the centre-line was made of?

Mr. FOULSTONE said it was made of fine steel wire, and was drawn up about 80 yards from the pit-bottom out of the way of shots.

Mr. T. A. SOUTHERN asked Mr. Foulstone whether he had found cases where, owing to the current of air ventilating the shaft or owing to water dropping, it had taken more than an hour to get the ordinary centre-line steady in a deep shaft?

Mr. FOULSTONE said the best way to centre the line was to stop the ventilation, either by stopping the fan or by putting in a shuttle without

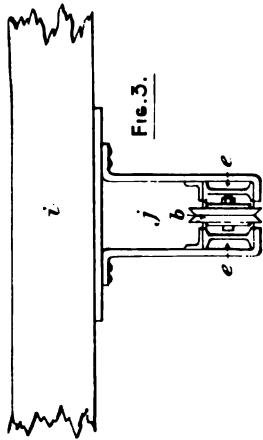


Fig. 3.



Fig. 4.

SECTION THROUGH A, B, FIGS. 1 & 2.

Fig. 1.

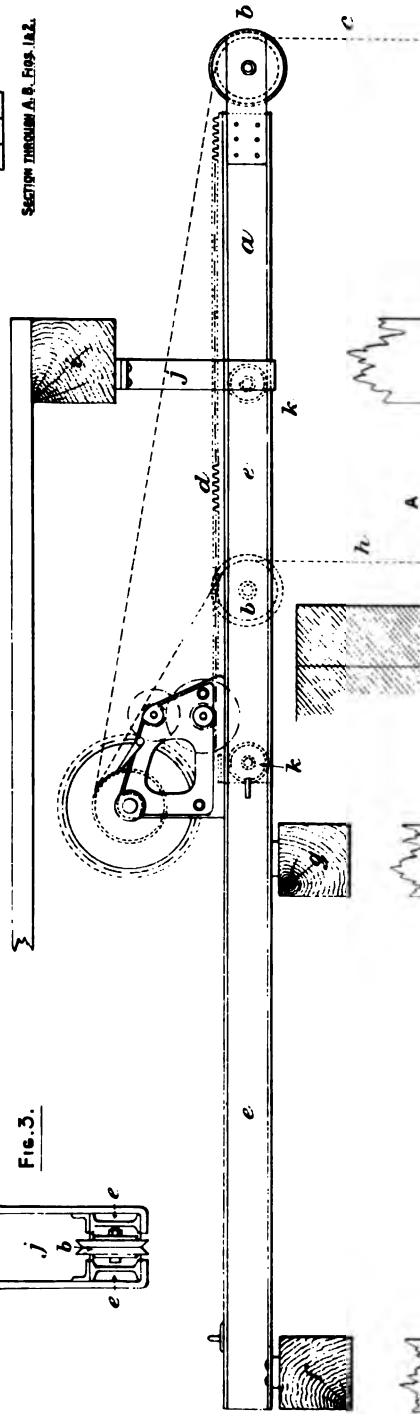
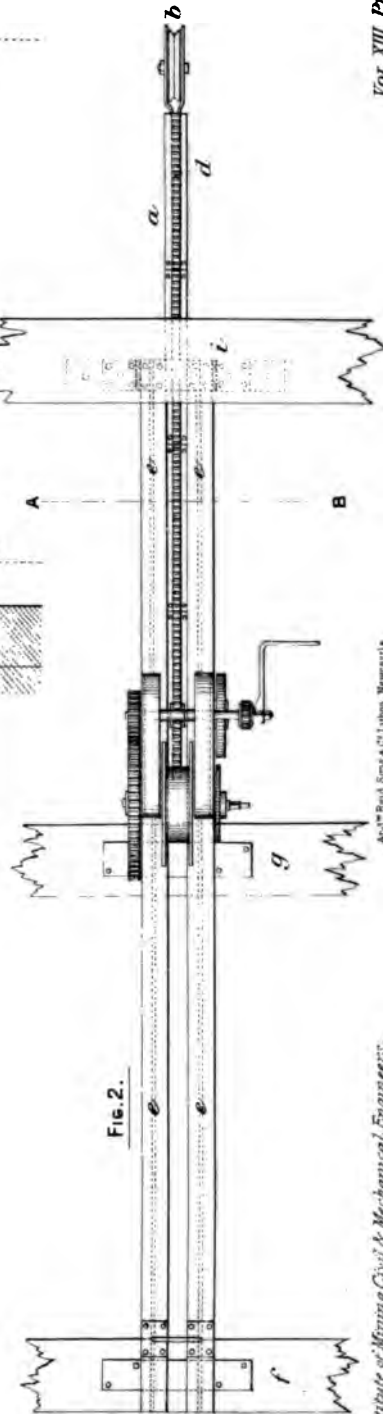


Fig. 2.





stopping the fan. The latter method was the best, because there was no fear of the fan-engine becoming choked with water.

Mr. I. W. H. WHITE said the apparatus was in use at Lord Masham's sinking, which will be sunk to a depth of about 600 yards, and it enabled the shaft to be centred accurately and quickly without the risk to human life which must occur when timbers, etc., had to be fixed temporarily every time the line was used. He felt sure that the cost of the apparatus was covered before the sinking reached a depth of 100 yards, and he would certainly adopt it in similar sinkings. The Foulstone apparatus was a cheap, ingenious, and neat arrangement, and when seen in use would be appreciated.

Mr. HENRY LEWIS proposed a vote of thanks to Mr. Foulstone for his paper.

Mr. W. WILDE seconded the proposition.

The CHAIRMAN agreed as to the utility of using a centre-line, especially in sinking through quicksands when side-lines could not be used. What objection could there be to the use of a piece of wood shaped in the middle and shod at the bottom with a piece of iron, so that when the wire was passed under the centre-pin they found the centre at once? There was danger in placing timber across the pit. Was there no danger of injuring the sinkers with this apparatus? There should be an arrangement by which the trolley could not get out of the groove.

The resolution was agreed to unanimously.

DISCUSSION ON PROF. F. CLOWES' PAPER ON "A PORTABLE SAFETY-LAMP WITH ORDINARY OIL ILLUMINATING FLAME, AND STANDARD HYDROGEN-FLAME FOR ACCURATE AND DELICATE GAS-TESTING" *.

The CHAIRMAN said that at the Derby meeting, Prof. Clowes described a method of detecting small percentages of fire-damp. The lamp had been tried at a colliery with which he was connected, and he found in a return passing 145,000 cubic feet of air per minute a cap $\frac{1}{2}$ inch in length indicating rather less than $\frac{1}{4}$ per cent. of gas. In another test he got a cap of $1\frac{1}{4}$ inches. He understood the pressure of hydrogen in the cylinders attached to the lamp was about 1,600 or 1,700 pounds per square inch. Each cylinder contained hydrogen sufficient for 80 to 90 tests, and in the two, they had provision for 160 to 180 tests. The cylinders could be sent by parcel post to be recharged in London, and while one was travelling the other could be used.

* *Trans. Fed. Inst.*, vol. iv., page 441.

Mr. OVEREND asked if this lamp was a test to compare with the ordinary lamp?

The CHAIRMAN said the lamp was proposed to be used with less than 3 per cent. of gas with the oil lamp, or less with the Pieler lamp, so as to form a reliable estimate of the volume of gas in the returns.

Mr. GEORGE LEWIS said their thanks were due to Prof. Clowes who had for some time past been perfecting the details of his lamp, but there was a certain amount of complexity about the lamp which made it very difficult to use for examination in the mine. He was told that a lamp, which would answer every purpose of this lamp, had been made which simply burnt alcohol instead of hydrogen. He was not sufficiently acquainted with the details to explain it, but he was informed that it would be described to the members at an early date.

Prof. A. LUPTON said alcohol had been tried many times. When Prof. Clowes first gave careful attention to the subject he commenced with alcohol, but after full and fair trial came to the conclusion that hydrogen gas was the best. He (Prof. Lupton) had had the advantage of seeing this lamp tried in the laboratory and in the mine. With an ordinary safety-lamp used in the ordinary way, they could see 3 to 5 per cent. of gas, but sharp eyes were needed to detect 1 to $1\frac{1}{2}$ per cent. even with the best forms of ordinary spirit lamp. With the alcohol lamp, 1 per cent. showed a distinct cap, but $\frac{1}{2}$ per cent. did not. With the hydrogen lamp, they had, with $\frac{1}{2}$ per cent. of gas, a cap about which there could be no doubt—a cap $\frac{3}{4}$ inch in length—which anyone could see. A cap had been seen with less than $\frac{1}{4}$ per cent. of gas. With that lamp, they had a simple and easy mode of examining the returns, and a colliery manager might learn to what extent his ventilation was clearing away gas. He could find what percentage of gas was produced in the mine; he could follow up the main return to the branches, and see which return was bringing most gas; he might find one district free from gas and another heavily laden. It was not necessary to put this lamp into the hands of all the deputies, but it might be used to make scientific tests of the air of a mine.

Mr. HENRY LEWIS said he disagreed with the assertion that the state of the returns was a true indication of the safety of the mine, so far as the existence of gas was concerned.

Prof. A. LUPTON said he had not referred to the safety of the mine; he was speaking of the volume of gas.

Mr. HENRY LEWIS said Prof. Lupton spoke of the quantity of gas that might be found in a district of the mine. There might not be the

slightest indication of gas in the returns, but there might be concealed in some part of the mine sufficient gas to blow up the colliery.

Mr. STOKES said Prof. Lupton stated that alcohol had been tried and found a failure; but Prof. Clowes told them the Pieler lamp, which burnt alcohol, was the best test they could get—there was no better test known. The only difficulty was that the Pieler lamp was not safe.

Prof. LUPTON remarked that was a serious objection.

Mr. STOKES said the Pieler lamp burnt alcohol, and Mr. Pieler especially recommended that methylated spirits should not be used. With Prof. Clowes' lamp, 1 per cent. of gas in the returns gave a cap of 22 millimetres (0·87 inch), while alcohol gave 90 millimetres (3·54 inches). A cap of 90 millimetres was better to read than one of 22 millimetres. Prof. Clowes' lamp gave a cap of 18 millimetres (0·71 inch) with $\frac{1}{2}$ per cent. gas, and the Pieler lamp 65 millimetres (2·56 inches); with $\frac{1}{4}$ per cent. of gas, the Clowes lamp had a cap of 17 millimetres (0·67 inch), so that between $\frac{1}{4}$ and $\frac{1}{2}$ per cent. of gas the cap only increased 1 millimetre (0·04 inch); but with the Pieler lamp, $\frac{1}{4}$ per cent. of gas gave 30 millimetres (1·18 inches) or 35 millimetres (1·38 inches) as the difference in the length of cap between $\frac{1}{4}$ and $\frac{1}{2}$ per cent. of gas. Between $\frac{1}{4}$ per cent. and 1 per cent., with the Clowes lamp they had a difference of 5 millimetres (0·20 inch), but with the Pieler lamp the difference was 60 millimetres (2·36 inches). The Pieler lamp was such a good indicator that with $2\frac{1}{2}$ per cent. of gas it became unsafe, the flame filling the entire gauze—it was too good a test. The most serious objection to the Pieler lamp was that another lamp must be carried to give light. The lamp Mr. Lewis had named burnt alcohol, but in a separate vessel entirely. This vessel was carried by the official in his waistcoat pocket and was filled with alcohol. The official had simply to introduce two threads of wick through a hole in the bottom of the lamp into the already lighted lamp, turn the light down, and the alcohol was left burning with a $\frac{1}{4}$ inch flame. The new lamp had been tested, and would indicate up to $2\frac{1}{2}$ per cent., but for 3 per cent. an oil flame would prove best.

Prof. A. LUPTON said that Prof. Clowes had no idea a rival lamp was going to be brought forward when he lent his lamp to be shown that day. He (Prof. Lupton) had tested the Pieler lamp many years ago, and while it gave large caps they were hardly visible. He had been in a mine with a Pieler lamp in a considerable amount of fire-damp, and while there undoubtedly was a large cap when they knew how to see it, yet it was not easily seen except by an expert in the use of that lamp. With

the hydrogen lamp anybody could see the cap clearly with $\frac{1}{2}$ per cent. of gas; the Pieler had not come into popular use owing to the difficulty of reading the indications and for other reasons.

The CHAIRMAN said he had no idea that another lamp would be mentioned when he stated that Prof. Clowes' lamp was now in practical shape. The time would come when most of them would desire to have a very sensitive test for showing gas in the returns. He agreed with Mr. Lewis that it would not be a final test in finding gas, or of the safety of the mine, but it was one of the tests which, in conjunction with others, would help them to make their mines safer.

Mr. J. B. SMITH asked if coal-dust affected the caps?

The CHAIRMAN said that he had been told that no test for gas was reliable in the presence of coal-dust.

THE ROYAL COMMISSION ON ROYALTY RENTS AND WAYLEAVES.

Mr. A. BARNES (one of the Commissioners), read a number of extracts from the report of the Royal Commission on Royalty Rents and Wayleaves, and promised to give further particulars at a future date.

Mr. JOS. MITCHELL moved that the best thanks of the meeting be given to Mr. C. E. Rhodes and Mr. W. Henry Chambers for allowing members to visit their collieries that day.

Mr. J. B. SMITH, as a member of the Chesterfield Institute, had pleasure in seconding the proposition.

The CHAIRMAN put the vote of thanks to the meeting, and it was carried unanimously.

Mr. GEO. LEWIS moved a vote of thanks to Mr. Garforth for presiding.

Mr. A. M. CHAMBERS seconded the motion, which was carried by acclamation.

Mr. THOMAS SETTLE, manager of New Mills gasworks, exhibited and explained to the members a working model of a safety-clip or catch which he had invented.

The members afterwards dined together.

The following notes record some of the features of interest seen by the visitors to the Rotherham Main colliery :—

ROTHERHAM MAIN COLLIERY.

The sinking of two shafts, each 18 feet in diameter, at this colliery commenced in 1890. The water is tubbed back with cast-iron tubbing at a depth of 84 yards in each shaft. Pulsometer pumps were employed to drain the water, the maximum quantity pumped being 120,000 gallons per hour from a maximum depth of 84 yards; nine No. 9 pulsometer pumps were in use at one time in one shaft.

At No. 1 pit, the main winding-engine has two cylinders 40 inches in diameter and $6\frac{1}{2}$ feet stroke, with round rope-drum 24 feet in diameter, and is fitted with steam reversing-gear. The cages will carry eight tubs of 10 cwts. each. During the sinking a flat rope-drum 12 feet in diameter was used.

The wrought-iron headgear for No. 1 pit will stand 60 feet above the pit-hill, which will be 26 feet above ground-level.

Screens and picking-bands are being erected.

The No. 2 pit was sunk by an engine with two cylinders, each 18 inches in diameter, which will be used for haulage purposes.

A winding-engine with two cylinders, each 20 inches in diameter, will draw coal from the high hazel seam, and an engine with two cylinders, each 30 inches in diameter, will wind from the Barnsley seam.

Some of the boilers are intended to be worked by the waste heat from coke-ovens. The remainder of the boilers will be hand-fired.

An air-compressor, put down for sinking purposes, is working drills and a Stanley heading-machine.

A Capell single-inlet fan, $12\frac{1}{2}$ feet in diameter, was used during the sinking, and will be kept as a reserve fan in case of accidents. The permanent fan will shortly be erected.

The electric light was used during the sinking operations and on the surface-works, furnished by a small oblique engine and a No. 4 Manchester dynamo.

The brick-making plant consists of one Fawcett semi-dry machine capable of making 12,000 bricks per day ; it is driven by a horizontal engine with two cylinders, each 18 inches in diameter. There are two Newcastle kilns, each holding 25,000 bricks, and two ordinary open-top kilns each holding 75,000 bricks.

MIDLAND INSTITUTE OF MINING, CIVIL, AND
MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE ROYAL VICTORIA HOTEL, SHEFFIELD,
APRIL 8TH, 1893.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen were elected Members, having been previously nominated :—

Mr. SAMUEL BARRACLOUGH, Mechanical Engineer, Union Foundry, Barnsley.
Mr. ED. BROOKE, Colliery Proprietor, Edgerton, Huddersfield.
Mr. GEO. RICHD. MAYES, Mechanical and Mining Engineer, Dukinfield
Collieries, near Manchester.

This being the date of the Joint Meeting with the Chesterfield and Midland Counties Institution of Engineers, the separate meeting of the Midland Institute was held *pro forma* for the election of members only.

**MIDLAND INSTITUTE OF MINING, CIVIL, AND
MECHANICAL ENGINEERS.**

—
GENERAL MEETING,

HELD AT THE QUEEN'S HOTEL, LEEDS, JUNE 24TH, 1893.

—
MR. W. E. GARFORTH, PRESIDENT, IN THE CHAIR.

—
The minutes of the last General Meeting were read and confirmed.

—
The following gentlemen were elected Members, having been previously nominated :—

Mr. ALFRED ASHLEY ATKINSON, Mining Engineer, Barrow Collieries, Barnsley.
Mr. WM. FOULSTONE, Colliery Engineer and Contractor, Barnsley.
Mr. FREDK. GABSIDE, Engineer, Wath Main Colliery, Rotherham.
Mr. WALTER MACHEN, Colliery Manager, Car House, Rotherham.
Mr. MOSES SOAR, Engineer, Warren, Chapeltown, Sheffield.
Mr. HARRY WORMALD, Engineer, Featherstone, Pontefract.

—
**DISCUSSION UPON PROF. CLOWES' PAPER ON "A PORTABLE
SAFETY-LAMP, WITH ORDINARY OIL ILLUMINATING
FLAME, AND STANDARD HYDROGEN-FLAME FOR
ACCURATE AND DELICATE GAS-TESTING."***

The PRESIDENT said that Prof. Clowes' safety-lamp for detecting small quantities of fire-damp would prove a most useful instrument. It had been used at Messrs. Pope & Pearson's collieries, and the deputies had been astonished, where they thought places free from gas, to be shown that $\frac{1}{2}$ per cent. was present. There was another lamp in preparation which would be cheaper than Prof. Clowes' lamp, but he did not think it would yield similarly accurate results.

Mr. J. NEVIN asked the President if he had tried the Pieler lamp?

* *Trans. Fed. Inst.*, vol. iv., page 441.

The PRESIDENT said he had not tried the Pieler lamp for the purpose of detecting small percentages of fire-damp. Prof. Clowes' lamp readily showed a cap indicating $\frac{1}{2}$ per cent., even with such a very large volume of air passing as 140,000 cubic feet per minute. The idea of its use was to trace back from the returns to the districts, so that they might find whence any marked percentage of gas was derived.

Mr. J. NEVIN asked what was the lowest percentage of fire-damp which could be indicated on Prof. Clowes' lamp?

The PRESIDENT said Prof. Clowes thought that $\frac{1}{4}$ per cent. of fire-damp could be detected, but when the percentage was so small he began to doubt the quantity, and should not like to go into a witness-box and say it was $\frac{1}{4}$ per cent.

Mr. E. W. THIRKELL said the halo on the top of the flame was as long in $\frac{1}{4}$ per cent. as in $\frac{1}{2}$ per cent. of fire-damp, but it was not so clearly and well defined. He had tested the lamp, and could confirm all the President had said.

Mr. NEVIN asked what percentage of fire-damp the Pieler lamp would indicate?

The PRESIDENT replied from $\frac{1}{4}$ per cent.

Mr. NEVIN—And from that up to an explosive mixture?

The PRESIDENT—Yes. Some people, he added, objected to finding small quantities of gas, especially when they had to record the same in the report books, but he considered that they ought to be reported, and that, if possible, the standard of inspection should be improved. When he brought out a little instrument some years ago which they could put into any crevice to get a small volume of gas, one man said to him "I am astonished an instrument should be invented for finding gas; if you could find out something the gas would not show on, it would be much better," then they should not be subject to the Inspector of Mines going down and getting a bag full of gas and squirting it over some flame or other, saying "There!"

Mr. NEVIN said the man could get his wish with the electric lamp.

Mr. THIRKELL said he had compared Prof. Clowes' lamp with an ordinary bonneted Mueseler safety-lamp burning colzaline, and found that 2 per cent. could be detected with the ordinary safety-lamp.

The PRESIDENT said Prof. Clowes had now got a scale attached to the lamp, and when it was perfected he would attend at their meeting and explain its use.

DISCUSSION UPON MR. E. BROWN'S PAPER ON "EXPERIMENTS UPON TWO GUIBAL FANS AT ST. JOHN'S COLLIERY, NORMANTON."*

Mr. E. BROWN said he had nothing to add to the paper, beyond remarking that in Table III., column 18†, they would see that column 11 ought to be divided by column 10, and not column 10 by column 11 as stated.

Mr. T. W. H. MITCHELL said that instead of saying the air should be divided by the engine-power to get the useful effect, it had been put the other way about.

Mr. BROWN said, with reference to the water-gauge experiments made at the inlet of the fans, that the chimney was situated at the left-hand side of Fig. 6, Plate XXII.

The PRESIDENT asked if the fans were being run in the same way now?

Mr. E. BROWN said they were.

The PRESIDENT asked if Mr. Brown had seen any reason to alter his opinion?

Mr. BROWN said he had not. The fans had been running in this way for three years and the results proved that they got the same volume of air with a less indicated horse-power with the two fans running together.

Mr. J. NEVIN said he supposed one fan was not large enough to do the work, and if it was run at such a speed that it would do the work they lost useful effect?

Mr. BROWN said that was so—from 12 to 17 per cent. of useful effect was lost.

The PRESIDENT asked Mr. Brown if he would recommend the use of two fans?

Mr. BROWN said he did not know. If they had two fans, they could run one while they repaired the other. He thought it would be as economical to put down two small fans as one large fan. He did not intend to propound any theory, but with two fans they obtained better results at a low speed than with a single fan at a high speed; both fans running together produced 131,985 cubic feet of air at 65 revolutions per minute, and it required the single fan to run at 80 revolutions to produce a similar volume of air.

The PRESIDENT thought it would be desirable if they could deduce certain leading facts from the experiments as to whether, in the case of new sinkings, or in old sinkings (where they intended putting down a

* *Trans. Fed. Inst.*, vol. iv., page 532.

† *Ibid.*, vol. iv., page 538.

fan to take the place of another fan or a furnace), this could be carried out with advantage. If they had got leading facts in their minds, it sometimes saved a large expenditure of money. That was what he meant by asking Mr. Brown if, supposing that he had to erect a new fan, the extra expense of having two fans would be repaid by the assurance that in case of a breakdown, he had a duplicate fan?

Mr. NEVIN said it was an interesting paper, because it was rare that they had the opportunity of testing two fans on the same mine, of seeing what one fan would do and what was the result of adding a second fan. He thought much might be said in favour of Mr. Brown's view that in some cases it might be better instead of getting one large fan and a duplicate engine, as they usually did, to duplicate both fan and engine.

Mr. T. W. H. MITCHELL suggested that the question might arise whether they would put down two excessively large fans, so that when one broke down they would not have to run the other at such a high rate of speed as Mr. Brown had had to run his, viz., to run at 91 revolutions to get the volume of air that he obtained with only 75 revolutions, when the two were running together.

Mr. NEVIN said the high speed would only be required in cases of emergency. They had a Guibal fan, and when putting in a new set of arms, they had to put on a temporary furnace, but even then could not work the whole pit. If they had had two fans, they would have run one at a high speed till the other fan was repaired.

Mr. BROWN said that was just what they were going to do. They were going to replace one fan, and should continue to work the pit with one fan until the other was replaced.

The PRESIDENT said the crystallization which would take place in the fan-shaft by constant running would lead to breakdowns. Any stranger, not an engineer, going to a colliery wondered that they should spend so much money in duplicating the engine and yet did not go beyond that. He thought in putting down a fan they should look at the time when they might have a high water-gauge. They could not sink pits in the future as they had in the past, but must prepare for a higher water-gauge, and therefore a small fan running at a high periphery-speed would be better than a large one.

Mr. TURNBULL said he was of opinion that a small diameter of fan would be more popular in the future.

Mr. W. HARGREAVES said that at Rothwell Haigh colliery, they had large fans 40 feet in diameter by 10 feet and 12 feet wide. During the last two years they had erected small Capell fans, and obtained much better

results. If they had an accident with a single fan, it was a very serious matter; with the Leeds fan it would require at least three or four weeks to replace the shaft. He believed the time would come when smaller fans would be more generally used, for in case of accident, if they could not work the whole pit with one fan they could at all events keep a part of it at work.

The PRESIDENT said he had examined a fan-shaft that had been working for twenty-three years, and looking at it through a magnifying-glass it appeared like the wrinkled forehead of an old man. The strokes had gone across it, showing its life had been run. He put in a best Yorkshire iron shaft, as he could not get the same uniformity in steel.

FRICTION-CLUTCHES.

The PRESIDENT said he had expected that a paper would be read by Mr. Hedley on friction-clutches, but up to the present it had not been received.

Mr. L. DOBINSON said he thought they had one of the best for pulling heavy weights up steep gradients up to 9 inches to the yard.

The PRESIDENT asked what was the greatest weight they had lifted?

Mr. DOBINSON said that had not been ascertained; their engine-plane would be extended for a further distance of 250 yards, when they would get the maximum weight, but they found the friction-clutch in use was able to do the work.

The PRESIDENT asked how many tubs were drawn in one set?

Mr. DOBINSON said they ran trains of three tubs, and there might be on this inclined-plane 24 full tubs.

The PRESIDENT: On a gradient of 1 in 4?

Mr. DOBINSON—Yes. He added that in another branch of the same colliery, on a gradient of 1 in 13 worked by the same friction-clutch, they ran about 20 tubs at one time.

**SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE
INSTITUTE OF MINING ENGINEERS.**

—
GENERAL MEETING,

HELD IN THE MASON COLLEGE, BIRMINGHAM, APRIL 13TH, 1893.

—
MR. W. F. CLARK, PRESIDENT, IN THE CHAIR.

—
The minutes of the last General Meeting and of the Council Meeting were read and confirmed.

—
It was resolved that a letter of condolence be sent to the family of the late Mr. Benjamin Callear, of Coseley.

—
The following gentlemen were elected :—

MEMBERS—

Mr. PERCY CAZALET, Mining Engineer, Perranporth, Cornwall.
Mr. W. H. FITTON, 6, Bersham Road, Wrexham.
Mr. W. FOGGO, Brereton Collieries, Rugeley.
Mr. FRANCIS EDGAR JACKSON, Mining Engineer, Stourbridge.
Mr. HENRY HERRIN JACKSON, Mining Engineer, Colley Gate, Cradley.
Mr. ISAAC MEACHEM, Jun., Mining Engineer, Bradley, Bilston.
Mr. JOSEPH POPE, Mining Engineer, Camborne.
Mr. G. SAINT, Jun., Vauxhall Colliery, Ruabon.

STUDENT—

Mr. WILLIAM IVAN SMITH, Mining Student, Blackheath.

—
REVISION OF RULES.

The SECRETARY explained the desire of the Council of the Federated Institution of Mining Engineers as to the Rules, and pointed out that they would have to be revised in order that the subscribers should consist of Ordinary Members, Associate Members, and Honorary Members, with Associates and Students, on the lines of section B of Bye-law 8 of the Federated Institution of Mining Engineers, and that, in pursuance of notice given at the last general meeting in accordance with the rules, this meeting was made special for the consideration of the subject.

Mr. H. W. HUGHES proposed that, as suggested, the rules be made to conform with those of the Federated Institution of Mining Engineers. He

moved the resolution with pleasure, mingled with regret. Some three years ago he was one of a small committee who made the rules of the Federated Institution of Mining Engineers, and he should certainly wish to ascertain whether it was intended that the Associate Members should ultimately become Ordinary Members, or whether the Associates should ultimately become Ordinary Members, because, so far as his memory went, they endeavoured to base their action in the matter upon the rules of the Institution of Civil Engineers, where the Associate Member is one who becomes an Ordinary Member. If that were not intended in this case, he did not think the Associate Members ought to have the power of voting. As far as the Institution of Civil Engineers were concerned, he believed the Associate Members ultimately became Ordinary Members, and had the right of voting, but Associates were men who never could become members and consequently did not vote.

The SECRETARY said that the extra amount paid by the Associate Members was, he presumed, considered sufficient to qualify them for voting. The order of the Institution of Civil Engineers was reversed, and in the Federated Institution of Mining Engineers, the Associates were certainly the class intended to ultimately become Members.

Mr. HUGHES said he might further observe that the Associate Members did not practise the profession of mining engineers, and were not quite entitled to give opinions on subjects of interest to mining institutions. Associate Members were manufacturers, or might be owners, but were at all events people who had no scientific standing, while Associates in days to come would take their position as Ordinary Members. The rules of the Federated Institution said nothing about voting, and if they agreed to them, should they allow Associates to have a vote and not Associate Members?

Mr. E. B. MARTEN thought that at present they should confine themselves to the alteration of the rules, so as to carry out the desire of the Council of the Federated Institution of Mining Engineers. The question of voting might be passed over for the present.

Mr. HUGHES then said he would simply move that the rules be altered as required.

Mr. W. B. COLLIS seconded the motion, and it was unanimously approved.

The SECRETARY then read a paper by Mr. F. G. Meachem, entitled "Notes on an Earth Explosion or 'Bump' at Hamstead Colliery":—

NOTES ON AN EARTH EXPLOSION OR "BUMP" AT
HAMSTEAD COLLIERY.

BY F. G. MEACHEM.

A bump (or earth explosion) occurred on November 5th, 1892, at 11 o'clock a.m., by which three workmen were injured:—Ez. Tudor and Wm. Tudor (pikemen), and Joe. Biddle (loader). These men were driving a road from A to B (Fig. 1, Plate XIII.) in the usual manner (Fig. 2, Plate XIII.) in the thick coal, 23 feet in thickness, and laying at a depth of 1,890 feet.

The road had crossed the main No. 2 north return and proceeded to 40 yards beyond, and there had been very little creep or grind, and practically no bumping. The road was heavily timbered with larch 6 to 8 inches in girth and well slabbed. Very little powder was used in driving the roads, and this circumstance helped to keep the sides strong.

When the road reached the point B, a tremendous burst-up took place, and in an instant the whole road back to the No. 2 north was nearly closed, only about 15 to 20 inches being left open on an average along the top (Fig. 3, Plate XIII.). The whole force of the blow seems to have been exerted on the right-hand side (going in) and to have knocked out the timber from the foot; and the bottom rose in some places, completely filling the road. The tub, which was loaded at the back, and the air-pipes were jammed up against the roof to the left side. All lights were blown out by the force of the explosion, and the place was instantly filled with inflammable gas from the face to within 4 yards of the main return airway, along which about 50,000 cubic feet of air per minute was passing. The explosion forced a door open at D, and the suction or the force of the main air closed it again, completely smashing it to pieces, none exceeding 2 feet long or 3 inches wide.

Two doors at E, 300 yards away, were forced open and closed again violently. Deputy Joe Gill who was more than 300 yards down No. 5 east road stated that "it turned the air and rolled overhead like thunder." The stallmen working in the No. 8 east road stated that "it turned the air, they felt the shock of the bump, and thought a serious explosion had

taken place." Fig. 4 (Plate XIII.) shows the average height of the road, and a rough section as shown in the bating when the road was afterwards being repaired.

The men who went to the assistance of the workmen who were in the road had to scramble over the top of the bars. They found that Ez. Tudor, who was in the back, close by the loaded tub, was the least hurt, as the tub had received the full force of the upheaval. His brother Wm. Tudor, who was at the back of the tub (next the return road) was found seriously injured by being jumped against the roof; he stated that "he was bending down and was suddenly banged up against the top, and crushed about the back and legs." He also said that "the right-hand side of the road burst up and tossed him against the left side and top." The loader, Joe. Biddle, was working 3 or 4 yards from Tudor and he was banged against the top and slightly injured. The door-boy said that the explosion opened his door and closed it again, smashing upon the return. He was much frightened and enquired "was that a bump?" from the men who came to help, and being told that it was, "he hoped that they would not have another in that road."

There are no "slip things" about that can be seen.

The main roads (Nos. 1 and 2 north) were driven in the year 1882, and both roads have been bated through the coal that was left underfoot, down to the rock at the bottom of the seam. The roads were being driven at the rate of 20 yards per week.

A very strange feature in this case was that the roof was uninjured; and now that the road is repaired, not the slightest trace of damage can be found above the bars, nor, so far as the writer saw, was a single bar broken at the time. The tub was badly crushed and had to be taken to pieces before it could be removed.

As a rule, most of the bumps occur in the bottom, and this undoubtedly points to the fact that pressure and not pent-up gases is the sole cause. A careful watching of the innumerable cases at this colliery has led the writer to the opinion that bumps are entirely due to weight, and that the driving of the road throws the pressure upon the sides of the place. This opinion is supported by the fact that, as a rule, the sides of the roads are broken for about 12 to 15 feet from the centre. The coal or rock left underfoot offers great resistance to the pressure of the side, and as soon as the resistance of the floor is less than the pressure of the down-weight, the explosion takes place, the point of breakage being the centre of the road.

The writer does not think that gas plays an important part in the occurrence of bumps, as there are as many cases without as with gas, and

the coal and adjacent rocks are too porous to resist the natural and constant oozing of any gas that may be present. The natural pressure of the gas has been tested by means of a borehole made 10 feet into the solid coal in a gateroad 700 yards away from any workings, and the pressure was not sufficient to heave out a clay stopping. If any gas is in the coal or adjacent rocks the bump brings it out: gas may help a little, but it is not the prime mover. Bumps rarely take place in the openings; it would appear that the larger space being opened gives the floor room enough to heave up, and the pressure of the sides and pillars is thus gradually eased off. As a rule the floor will rise 5 to 6 feet before an opening is cleared out.

The pressure and temperature of the air is shown in the following table :—

Date.	In Pit.				On Surface.	
	Barometer.		Thermometer.		Baro- meter.	Thermo- meter.
	A.M.	P.M.	A.M.	P.M.		
1892.	Ina.	Ina.	Dega F.	Dega F.	Ina.	Dega F.
November 3rd...	31.65	31.50	59	63	29.34	44
„ 4th...	31.60	31.50	61	60	29.30	51
„ 5th...	31.55	31.60	63	65	29.40	51

The records show that there was no change of atmospheric pressure in this case.

Prof. T. McK. Hughes speaks* of Mr. Strahan's paper on "Explosive Slickensides," and then proceeds to give his own experience at Dent-head and Ribble-head, in Yorkshire, as follows :—"In the limestone quarry from which the black marble of Dent is procured the workmen found that when they were quarrying the lower beds and struck the rock with a pick or bar, fragments flew up into the air with greater force than could be due to their blow, and in an unexpected direction. Also when the tunnel was being made above Ribble-head, and the workmen were engaged upon the bed of rock which formed the floor of the tunnel, pieces used to burst off with a loud noise, so that some thought they had discovered a detonating shale." The explanation in both cases seemed to be that the bed, which was apt to shell off in that unexpected manner, rested on a shale which yielded to the superincumbent weight on either side, and produced in the tunnel or in the quarry where the overlying rock had been removed an effect similar to "creep." Fig. 5 (Plate XIII.) shows the manner of occurrence of bursting

* *Geological Magazine*, November, 1887.

rock at Dent-head and Ribble-head, in Yorkshire, the direction of the pressures being shown by the arrows. The shale would transmit the pressure; the thin bed of solid rock left above the shale was not compressible, and where, as in the tunnel or in the centre of the quarry, the weight of the overlying rocks had been removed, it rose in a slight arch over the upthrust shale, and was thrown into such a state of tension, that when struck, chips and flakes and sometimes larger pieces would fly off.

It should be remembered in connexion with like enquiries that time is an element in the bending of rocks, and that it is the rapidity of the action due to the artificial removal of the overlying mass that causes the rocks to break most violently.

Mr. J. Dickinson, H.M. Inspector of Mines, describes the occurrence of outbursts of soft coal and gas at the Broad Oak colliery, Ashton-under-Lyme, in his annual reports for the year 1890 and 1892, and more recently before the Manchester Geological Society.*

Mr. Fairley states† that bumps are miniature earthquakes caused by local pressure.

It seems utterly impossible to fight against these bumps, but considerable relief has been obtained by means of boreholes and jackey pits. In 1881-2, a series of bumps took place, and it seemed at one time almost impossible to drive any new roads without the certainty of men being injured. The most effectual preventive means were boreholes made through the coal and holes cut down through the underlying strata. Where the roads are not urgently wanted, it is better and safer to drive them as slowly as possible, which gives the pressure time to become gradually balanced. When a road is being driven night and day it opens the coal so fast that there is a constant weight on the face, and when the side weight asserts itself, it has a longer length over which to relieve itself than if it had been gradually following up the face. In the final report of H.M. Commissioners appointed to enquire into accidents in mines‡ among other recommendations they suggest "G. Driving the working places as rapidly as possible, by shifts of an ample number of workmen in each place, and so reducing the risk of falls and exposing the least number of men to danger at any one time."

This recommendation evidently does not apply to thick coal-mining at great depths, for such places have often to stand to settle themselves, and in actual experience the more slowly a road is driven the less danger occurs from bumps.

* *Trans.* vol. xxii., page 239.

† *Colliery Manager's Pocket Book*, 1888, page 196.

‡ Page 15.

FIG. 3.

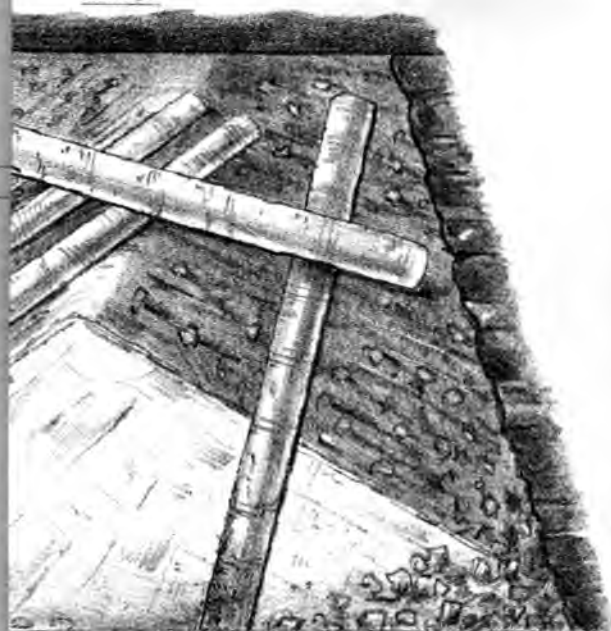
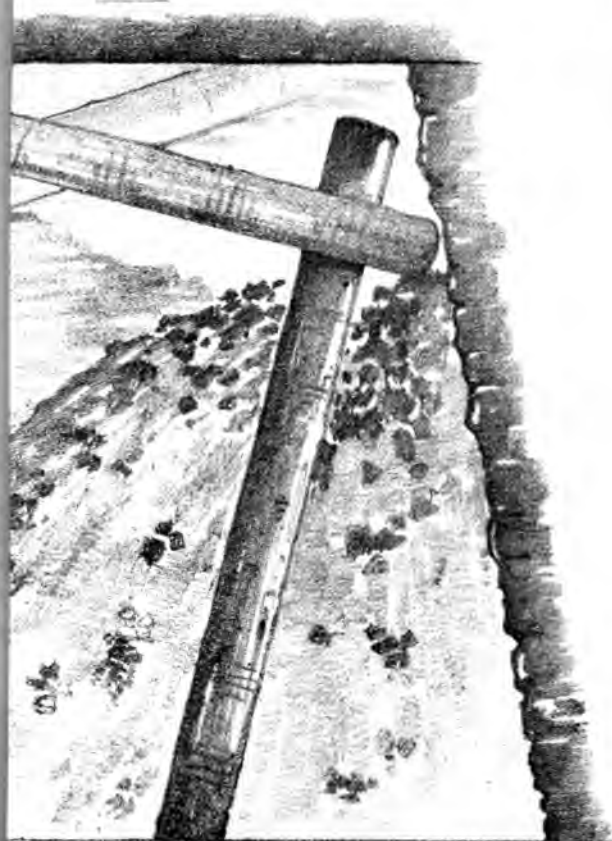


FIG. 4.



Another point which can be taken as a rule is that when the roads are being driven with the grain of the coal, the bumps come principally from the top and are not so heavy as in roads being driven across the grain, in which the bumps come from the bottom.

When roads have cut and rashed over the settings often to the rock above, a bump in the top simply shakes the fine loose slack down, and does not often break the timber; but a bump from the bottom under these conditions usually knocks the timber out at the foot, and then up goes the bottom and down comes the coal and slack from over the bars, with the certainty of seriously injuring whoever may be about.

It will be seen that to a certain extent bump may be looked for and in a measure guarded against. (*a*) When roads are being driven with the grain of the coal bump occurs from the top, and the timbering should be attended to; (*b*) when roads are being driven across the grain, bump occurs from the bottom; (*c*) the roads should at all times be driven slowly, jackey pits should be cut down into the bottom measures; and (*d*) boreholes should be driven into the top coal.

Prof. W. E. BENTON read the following "Engineering Scraps in Australian Coal-mining":—

ENGINEERING SCRAPS IN AUSTRALIAN COAL-MINING.

BY W. E. BENTON.

During the writer's absence from England he has, for a time, lost the benefits of fellowship with this Institute, but much of the good of our mining institutions is felt even unto the ends of the earth. A colonial member is, by custom, expected in reading a paper, to describe some far-distant mineral deposits; however, with the hope of being more interesting, allow me to refer to a few engineering scraps in Australian coal-mining.

UNDER-REAMING IN DEEP BORINGS.

In boring for coal with the diamond drill under Sydney Harbour, it became necessary to increase the diameter of the bore for the purpose of driving the casing-tubing lower. That necessity led to the invention of what the writer believes is a new form of under-reaming tool. This tool (Figs. 1 to 10, Plate XIV.) consists of a pair of mild steel levers, hung scissor fashion in a steel tube. On their upper ends, a loose cast-steel disc rests, which may be depressed about an inch by means of water-pressure from the steam-driven pump. By this depression of the disc, the lower ends of the levers are swung outwards through two slots in the steel tube. The cutting diamonds are set on the extreme edges of these levers. While the reamer is being lowered down the bore, the levers hang entirely within the tube; when the reamer has reached the required position, the steam-driven pump is started, the steel disc is depressed, the levers swing outwards and the reamer revolves by the starting of the drill.

The entering-cut of the reamer is made by lateral abrasion of the diamonds, forced outward by water-pressure on the disc; and afterwards the cutting is downward, the reamer being kept to its work by the weight of the boring-rods. During the downward-cutting, the water passes through the portholes in the steel tube, and impinging on the diamonds, removes the detritus. On raising the bore-rods, the levers on striking the first obstruction, are forced into the tube.

This tool can ream a 4 inches hole to a $4\frac{1}{2}$ inches hole in coal-bearing strata at the rate of about 6 feet per hour. It weighs about 20 lbs. and costs £8 without diamonds.

COLLIERY RECORDS OF LABOUR COSTS.

All items of labour costs and output may be shown graphically, if the pages of a book are equally spaced by 26 vertical dark lines, each of which may represent the 26 fortnights of a year. The upper part of the page being equally spaced by horizontal dark lines drawn from margin to margin, each space may represent 1,000 tons, and if each space contain 10 horizontal faint lines they may each represent 100 tons. On this upper part of the page the gross output, the various qualities, and the balances of pit and sales weights, may be shown each fortnight by various distinctive lines.

The lower part of the page being equally spaced by horizontal dark lines, each space will represent one shilling, and each may be subdivided by 12 faint horizontal lines representing one penny. On this lower part of the page, the gross costs and detail costs may also be shown each fortnight by various distinctive lines. Each page of this book will represent one year, and if the paper is translucent, in recording the outputs and costs of any succeeding year, the outputs and costs of the preceding year are manifest. The fortnightly records can be made in five minutes, and the writer has found this graphic register an impressive and interesting record of colliery outputs and costs.

SKIP OR CORVE UNDERFRAMES.

A specially simple form of underframe consists of two sole-bars, each 5 inches square, placed 18 inches asunder, for 2 feet gauge. Between these sole-bars, at each end, is bolted a piece of channel-steel bent at each end, which serves the double purpose of transome and draw-hook. The weight of each transome is 14 lbs. It is successful in flat mines for 25 cubic feet skips, slow speeds and single-skip attachments, but it has not been tried under other conditions. It is lighter, cheaper in first cost and in repairs, than wooden transomes and wrought iron drawbars.

HEATING IN THE BEARINGS OF HEAVY FAN-ENGINE SHAFTS.

The writer is of opinion that the heating of the bearings might be avoided in new erections by using hollow steel shafts. Prof. Unwin, in his *Elements of Machine Design*, gives an example of a shaft having a diameter of 10.09 inches and a hollow cylinder of 4 inches in diameter, as being equal in strength to a solid shaft 10 inches in diameter. The weight of such a hollow shaft is about 14 per cent. less than the weight of a solid shaft. Disregarding the slight difference in their diameters, there would be about 14 per cent. less friction and about 14 per cent. less heat-

ing arising from the weight of the shaft. The heating from friction of hollow shafts of ventilating fans would be further reduced by the current of air, which would be drawn by the fan through the hollow of the fan-shaft. If hollow fan-shafts have already been tried, it would be interesting to know whether the bearings have become heated, and whether the reduced friction has added to the useful effect of the fan.

COAL TIPPERS.

In recent years coal skip-tippers have been greatly changed in form, the best form being that in which the skips pass out at the opposite end and lay down the coal with least breakage. Fig. 11 (Plate XIV.) exhibits a form of tipper, which has in practice been found to fully possess every requirement. It resembles an overshot waterwheel, three compartments being built round a horizontal shaft. Each compartment holds either one skip, or two skips, buffer-to-buffer.

In starting to tip, the floor of one of these compartments is standing at the ground-floor level. Revolved through a third of a revolution, it brings round another compartment to ground-floor level; and each compartment may in turn be brought to platform level. In one compartment the skip is full, in another the skip is emptied into a pocket in the tipper, and the third compartment has laid its coal on the screen.

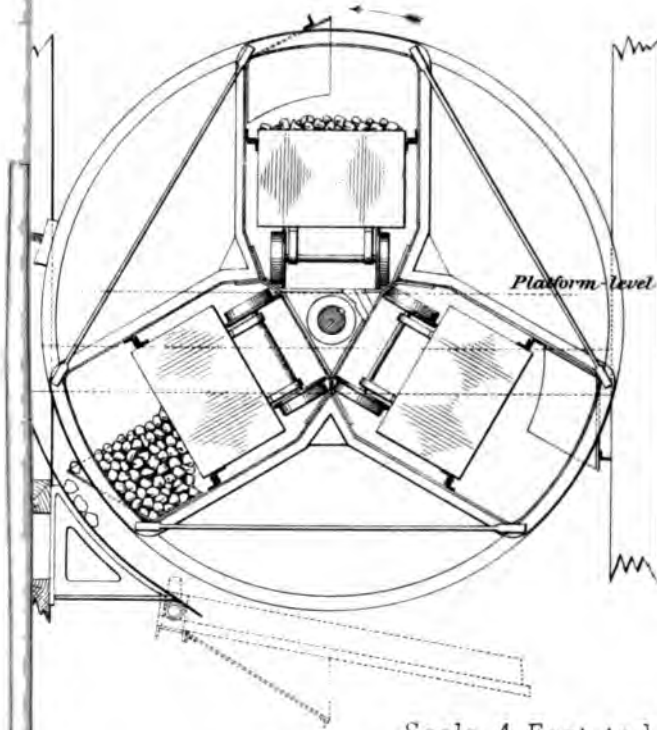
During each whole revolution three skips are emptied, that is one from each compartment, or two if placed buffer-to-buffer in each compartment. The weight of each preceding skip assists in tipping its successor, and by this triple arrangement the best balancing is obtained. By a hand-power brake, the loaded speed of the tipper is perfectly governed at any point of a revolution.

This form of tipper does not break the coal, and one boy can easily tip as much coal as the mine can raise. Its entire weight is 50 cwts., and the cost, complete in New South Wales, does not exceed £80.

—

Mr. TREGLOWN, in reply to the President, said, with reference to the heating of fan-shafts, a very great deal depended on the design, whether the shafts were made of suitable material, were of proper size for the work, had ample bearing-surfaces, and sufficient lubrication. He thought that the passing of a rapid current of air through a hollow-shaft would tend to keep it cool.

FIG. II.



Scale-4 Feet to 1 Inch

SKIP-TIPPER.

E

G

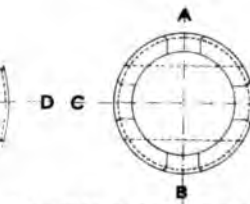
J

K. FROM BELOW.

SEC

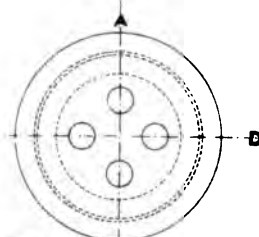
FROM BELOW.

FIG. 5.



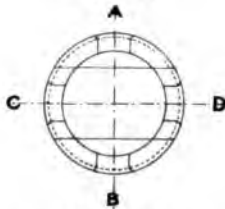
SECTIONAL PLAN OF PISTON THROUGH E.F.

FIG. 6.



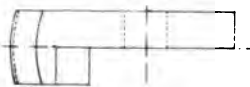
BOTTOM PLAN.

FIG. 8.



PLAN OF PISTON.

FIG. 9.



PLAN OF TOOL.



Mr. N. CHANDLER observed that he had had occasion to make an enquiry for a hollow fan-shaft; a prohibitive price was quoted of £120, so he bought a solid shaft for £60, which was now running with complete success, and had run for nearly two years without any trouble. He was, however, entirely in favour of the use of hollow shafts, when price did not prohibit their use. He also stated that exhaustive tests had proved that a hole bored through a steel shaft, half the diameter of a shaft, only diminished the strength of the shaft by 4 per cent. for torsion or twisting, while its weight was reduced 25 per. cent.

Mr. F. G. MEACHEM believed if the bearings were in line, and good grease was applied, the shafts would not become very much heated.

Mr. GLENNIE, alluding to the suggested graphic records of wages and outputs, said he had used them many years ago, at a colliery, but he found great difficulties at a larger colliery, where the records had to be kept on a much more detailed plan: it then became almost impossible to record them graphically. The coal-tipper resembled Riggs, but the latter had not the advantage of running the tub right through, and only took one tub instead of three, so that described by Mr. Benton was a great improvement.

Mr. H. W. HUGHES said that when making enquiries some time ago as to coal-tippers, he came to the conclusion that the machine-tipper was far in advance of anything worked by a brake. The motion was more regular in a machine-driven tipper. He had seen one in use, which tipped four tubs at a time.

Mr. BROUGHALL said he had used two tippers, driven by machinery, for about five months, and the cost was from 6½d. to 7d. per 100 tons.

The PRESIDENT said that two years ago he went into the question of machine-driven tippers, and he came to the very same conclusion as Mr. Hughes.

On the motion of the PRESIDENT, seconded by Mr. H. W. HUGHES, the thanks of the members were accorded to Mr. Meachem and Mr. Benton for their papers.

**SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE
INSTITUTE OF MINING ENGINEERS.**

GENERAL MEETING,

HELD IN THE MASON COLLEGE, BIRMINGHAM, JUNE 8TH, 1893.

MR. W. B. SCOTT IN THE CHAIR.

Upon the motion of the CHAIRMAN, it was unanimously resolved, that a letter of condolence and sympathy be sent to the President (Mr. W. F. Clark), who was absent through illness, and had recently suffered from severe domestic troubles.

The minutes of the last General Meeting and of the Council Meeting were read and confirmed.

The following gentlemen were elected :—

MEMBERS—

Mr. EDWARD W. JANSON, Mining Engineer, Camborne.

Mr. GERALD LONGLEY PARKER, Mining Engineer, Chester.

The CHAIRMAN read the following "Description of Mining Relics found at the Heath End colliery," belonging to Messrs. John Hough & Son, and on their behalf he presented them to the Institute, and a vote of thanks was unanimously passed to them :—

DESCRIPTION OF MINING RELICS FOUND AT THE HEATH
END COLLIERY.

The relics consist of a coal-waggon, which was discovered in the old shallow seam workings, made probably 200 or 300 years ago, at a depth from the surface of from 15 to 16 yards. When found, it was loaded with small coals, with the twigs interlaced between the short upright pieces which were firmly fixed in the holes on the bottom of the waggon. The bow was threaded between two holes at either end of the waggon and fastened with a peg through a small hole in each end of the bow. It is presumed that this was the way the coals were raised to the surface. The probable weight of coal on the waggon when discovered would be from 50 to 60 lbs. The dog-hook lay close beside the waggon, which would be the means of, at that time, pulling the coals to the shaft. Shafts are very numerous at the outcrop of the coal-seam, and, as far as can be traced, the old miners never ventured more than 70 to 80 yards from the pit-bottom. It is easy to note the advance of mining engineering, since our forefathers relied upon such primitive means to win the valuable treasures of the earth.

Mr. HERBERT W. HUGHES read the following paper on "The Spontaneous Combustion of Coal":—

THE SPONTANEOUS COMBUSTION OF COAL.

By HERBERT W. HUGHES.

The question of the spontaneous combustion of coal is of such importance to the South Staffordshire district that an apology is not needed for bringing the subject before the members of this Institute; but inasmuch as the writer has already contributed a rather extensive paper* on this question, and has, in conjunction with Mr. W. F. Clark,† also given a brief summary of the conditions under which the spontaneous combustion of coal is likely to occur, some explanation may not be out of place as to why he again brings the matter before you.

In the first place the paper referred to above is not generally accessible to members of the Federated Institution; and secondly, the subject was revived by Mr. Arnold Lupton‡ at the Derby meeting of that Institution. The latter contribution brought out a very interesting discussion, but the time devoted to it was necessarily short. Many contradictory opinions were also expressed. Unfortunately, this district provides excellent opportunities for studying the question, and most of our members are in the unpleasant condition of having considerable practical experience of underground fires. It was therefore suggested that if the various theories were brought together and summarized, a valuable discussion might be raised, which would assist engineers in determining the conditions under which coal ignites spontaneously, and indirectly prevent such fires, as the conditions likely to cause them may be avoided. In considering the question the writer will be traversing old ground, but this must be done in order to bring into prominence the various agencies by which spontaneous ignitions are caused.

At the beginning of Mr. Lupton's paper some remarks are made about fires produced by ranges of steam pipes and furnaces underground; however, as the causes of such ignitions are obvious, the writer does not propose to consider them, but to confine himself to dealing with those fires which commence truly spontaneously, viz., without the application of any external heat. This paper, and the discussion, will be referred to many

* *Trans. South Staffs. Inst. Min. Eng.*, vol. xi., page 33.

† *Trans. Fed. Inst.*, vol. iii., page 45.

‡ *Ibid.*, vol. iv., page 481.

times; but perhaps at this point it will be as well to correct a small misstatement made when speaking of the size of sides of work in the ten-yard seam. Rarely (if ever at the present time) does one of those panels measure 80 or 100 yards square, or contain sixteen or twenty pillars. The most common size is one having six pillars, which, if these were of the largest dimensions, would measure 70 by 50 yards, but more generally the pillars would only be 8 yards square. A side of work containing nine pillars is considered a large one, and is perhaps not so frequently met with as one having only four pillars.

It has been often remarked that the first sign of spontaneous combustion is the emission of the peculiar odour known to the miner as fire-stink, and when this is recognized, there is little doubt that if fire is not already existent it soon will be, as the smell is due to the volatile hydrocarbons given off by destructive distillation of coal. At the Derby meeting, Mr. Clark pointed out that there is, however, an earlier sign than this, and one well-known and detected by an old thick-coal miner, viz., a peculiar musty and old smell, which is not easily described; perhaps the nearest resemblance to it is the odour given off by a collection of old parchment deeds. Another sign preceding the emission of fire-stink is the sweating of the coal which so often takes place before ignition. This sign is, however, in many cases misleading, as sweating is often produced by a leakage of fresh cool air through doors, etc., meeting the hot vitiated return air, and causing moisture to be deposited on the roof and timbers. Indeed neither of the two last mentioned signs are so reliable a warning as the first-mentioned one, as both of them may be noticed without any fire following, while the detection of fire-stink generally means trouble. In many cases no sign is given, and an outbreak occurs without warning. Mr. Clark and the writer gave an illustration of this in the paper previously referred to, and if there were any necessity to do so numbers of similar instances could be quoted.

The spontaneous ignition of coal is ascribed to:—(1) decomposition of iron pyrites; (2) pressure; (3) oxidation of the organic constituents.

It seems advisable to consider each of these actions separately before dealing with them in conjunction, although the writer hopes to prove that neither of the two first-mentioned actions are especially dangerous, unless acting in conjunction with the third one.

(1) *Iron Pyrites*.—Probably all coals contain sulphur in some combined form, the usual compound being the bisulphide of iron (FeS_2). This generally occurs in nodules, flakes, and veins, which, from their brassy appearance, readily attract the eye. On many occasions, iron

pyrites is found in the form of a dark powder distributed through the mass of coal, and scarcely to be distinguished from it. This is a point of considerable importance, and will be alluded to farther on.

In the presence of moisture and air, pyrites sometimes oxidizes very readily, while at other times no action takes place. One of the South Staffordshire seams supplies a good illustration of the stable properties of iron pyrites, viz., the stinking coal, which contains such large quantities of that mineral that heaps of it are picked out at bank and thrown aside. These heaps accumulate often for years, and are subsequently sold to chemical manufacturers. No instance of their having ignited is on record, although they contain a good proportion of coal and carbonaceous shale, and, moreover, the weathering of the pyrites amounts to practically nothing.

Pyrites first oxidizes into ferrous sulphate and then passes into the ferric salt. The increase in temperature is small, but as the pieces of pyrites become coated with crystals of sulphate, the volume of the decomposed mineral greatly exceeds the bulk of the original substance and disintegration of the coal takes place. It is also asserted that ferric sulphate is reduced to ferrous sulphate by contact with coal and that consequently the oxidation of the coal itself is increased.

The amount of heat given off by the complete combustion of a known quantity of sulphur may be easily estimated with a calorimeter. Now, many coals extremely liable to spontaneous combustion not only contain a small quantity of pyrites but the pyrites is scattered. Supposing, however, that the whole of the pyrites was concentrated in one spot and was oxidized in a comparatively short space of time, it is possible to prove by the above-mentioned experiment that the heat produced would be too insignificant to raise the temperature of the coal more than a few degrees.

Prof. Lewes* states that as free sulphur is produced by the oxidation of masses of pyrites under certain conditions, and as sulphur has an igniting-point of 250 degs. C., his earlier experiments led to the belief that this free sulphur might play an important part by lowering the point of ignition; his later experiments, however, show that this could only take place with large masses of pyrites and that with the amounts present in coal, if the air were present in sufficient quantity to oxidize the pyrites, the small trace of sulphur liberated would be oxidized to sulphur dioxide at temperatures as low as 60 degs. C. He further determined the igniting-point of various kinds of coal and found that:—

* "The Spontaneous Ignition of Coal and its Prevention," *Journal of the Society of Arts*, vol. xl., page 354.

			Dega. Fahr.	Dega. C.
Cannel coal ignites at...	...	...	698	= 370
Hartlepool coal ignites at	...	...	766	= 408
Lignite coal ignites at...	...	...	842	= 450
Welsh steam coal ignites at	...	...	870.5	= 477

and significantly adds that no stretch of imagination could endow the small traces of pyrites scattered through a large mass of coal, and undergoing slow oxidation, with the power of reaching the needful temperature.

The late Dr. Percy* also emphatically expressed a similar opinion, and every eminent scientist who has studied the question agrees with such conclusions. It is therefore difficult to understand why so many people still believe that pyrites plays the principal *role* in spontaneous ignitions; it can only be accounted for by the fact that the bright sparkling pieces of pyrites are very prominent when mixed with coal, and that the disintegrating action produced by their decomposition is often equally self-evident, while the oxidation of the organic constituents of coal cannot be seen and is only heard about through experiments conducted by scientific persons. Tennyson's line—

"Things seen are mightier than things heard,"

applies very well here.

(2) *Pressure*.—So far as underground fires are concerned there can be little doubt that the pressure from the roof plays, in some cases, a very important part. In addition to the heat produced mechanically by the crushing and fracturing of the coal and the grinding of the irregular sides of these fissures together, a large amount of coal is produced in a very fine state of division and passages are made into the sides of ribs and pillars, which readily admit a small amount of air to supply oxygen to intensify the action.

The arguments in favour of this agent are strengthened by the fact that underground fires occur more frequently in thick seams where the roof pressure is great than they do in thin seams. Everyone who has mined coal where the seams are thick will willingly admit that such is the case. The ten-yard seam of South Staffordshire is unfortunately a prominent instance, but it does not stand alone in enjoying such an unenviable notoriety. The thick seams of the central district of France, of Silesia, and many lignite-mines on the Continent are equally subject to such outbreaks.

The writer's own experience leads him to strongly assert the importance of such action. Where the ten-yard seam is subject to much weight (either by a side of work standing for a length of time, or when a district

* *Metallurgy, Fuel, etc.*, 1875, page 299.

is being finished, and the coal on three sides of the chamber which is being worked has been taken out), the pillars become much fissured, and fires readily break out unless the greatest care and supervision are exercised. The action which takes place appears to be that as the irregular sides of the fissures are ground together, the mechanical heat produced is concentrated on the surfaces in contact, while the small coal formed by the grinding action is acted on by this heat and subjected to a process of destructive distillation and also oxidized by the air passing into the cracks; in addition, the heat produced is confined and cannot readily escape.

Similar opinions are expressed by Mr. Durand* in a paper dealing with underground fires at Doyet collieries in the department of Allier, France, where the seams are not only of great thickness (sometimes more than 20 yards) but are inclined at steep angles. This paper, however, contains several statements to which exception may be taken, and these will be noticed later on. It is the only paper of recent years (that the writer is acquainted with) which attempts to prove that pyrites plays the most important part in promoting spontaneous ignitions.

(3) *Oxidation of the Organic Constituents*.—Although many years ago the general opinion was that the decomposition of pyrites played the chief part in producing spontaneous fires, yet even in 1864 an opinion was expressed by Dr. Percy† that it was not the chief agent, and that there was another cause similar to that which determined the spontaneous combustion of cotton-waste, viz., the absorption of oxygen by coal reduced to a fine state of division.

It was, however, left for Prof. E. Richters‡ to substitute fact for opinion. His experiments were summarized by Dr. Percy who expressed an unqualified belief in their correctness, and similar opinions have been given by numerous other observers who have conducted similar investigations.

Prof. Richters' experiments have been quoted so often that it is not necessary to quote them again here. The chief points he established were that all coals, especially when freshly won, absorb oxygen even in extreme cases to three times their bulk; that an increase of temperature takes place through such action; that such increase of temperature increases the amount of absorption; and that the power of coal to absorb

* "Note sur les incendies dans les houillères," *Bulletin de la Société de l'Industrie Minérale*, vol. xii. (2nd series), page 43.

† *Metallurgy, Fuel, etc.*, page 298.

‡ *Dingler's Polytechnisches Journal*, 1870, vol. cxcv., pages 315 and 449, and vol. cxevi., page 317.

oxygen is never entirely lost. He also demonstrated that the quantity of oxygen absorbed by different coals under the same conditions is proportionate to the quantity of water which they absorb.

Mr. J. W. Thomas* and Prof. Lewes† both support such views and point out as a similar instance, the rapid absorption of oxygen by freshly-prepared charcoal, which produces such an amount of heat, that in the manufacture of this substance it always has to be kept three or four days after burning in air-tight cylinders before picking over and then must remain ten or fourteen days before being ground or ignition would take place. Indeed, after grinding, it has to be kept in small heaps, as a quantity of 100 bushels or more, if collected in one mass, would always ignite. In the case of charcoal, the heat produced by the absorption of oxygen results from purely mechanical causes due to the rapid rush of the gases through the capillary tubes forming the pores of the material. Charcoal indeed is a most stable body, and after being properly manufactured remains unaltered in the air for a long period of time. It is the only highly carbonized compound liable to spontaneous ignition, and this is accounted for by its great porosity and minuteness of division and its combustible properties.

All coals contain a certain percentage of volatile matter, and when oxygen is absorbed it enters into combination with the carbon and hydrogen of the bituminous matter and forms carbonic acid gas and water vapour. Oxidation of any kind is always accompanied by an increase in temperature, which again reacts and increases the rapidity of chemical combination. Both the action and reaction therefore conduce to a steady rise in temperature, and if it takes place in heaps of coal, which are naturally good non-conductors of heat and are sufficiently porous to allow sufficient air to enter to supply the necessary oxygen for continuing the action, the temperature may easily rise to the igniting-point.

The above is the theory of the subject and is supported in a most marked manner by practical results obtained underground. When any working-place is about to fire, large quantities of carbonic acid gas are invariably given off, and, in addition, the coal commences to sweat.

If further arguments were necessary, the elaborate experiments conducted by Mr. H. Fayol‡ might be quoted. He concludes that the rise of temperature accompanying the absorption of oxygen from the atmos-

* *Coal, Mine-gases, and Ventilation*, London, 1878, page 245.

† *Journal of the Society of Arts*, vol. xl., page 353.

‡ "Etudes sur l'altération et la combustion spontanée de la houille exposée à l'air," *Bulletin de la Société de l'Industrie Minérale*, vol. viii. (2nd series), page 487.

phre by finely powdered coal is the chief cause of its spontaneous ignition. He further states that only a low temperature is needed to ignite powdered coal, lignite igniting at 150 degs. C. (302 degs. Fahr.), and anthracite at 300 degs. C. (572 degs. Fahr.).

General Considerations.—Having considered each agent separately, we may now consider the subject as a whole. Mr. Durand appears to be the only writer who elevates the oxidation of pyrites into being the chief cause of ignition. He states that at the Doyet collieries the roof over the thick seam is composed in some places of a fine shaly sandstone containing pyrites, and that near the outcrop, where cracks have occurred in the roof, it has got red hot and has sometimes set fire to the timber props. He admits that it is difficult to account for fires in seams free from pyrites, and subsequently adds that near the outcrop with partial open working the coal has been set on fire by the frictional heat produced by a sudden slip of the roof above.

To a certain extent pyrites may materially assist the action of oxidation, and more especially so if it is in a fine state of division. Indeed, when in the form of a dull amorphous powder it becomes dangerous, but even then indirectly. When finely disseminated through coal or shale pyrites seems to possess a more porous character than appertains to it of itself, and often readily decomposes. Not only does this produce heat and thus render the coal more susceptible to oxidation, but it also rapidly disintegrates the coal and exposes a larger surface to the action of the atmosphere. Under such conditions if pressure be acting as well, a fire may arise in an incredibly short space of time.

When pyrites exists in lumps, little or no danger is to be apprehended from this cause. Mr. Fayol exposed pieces of coal of the size of the fist containing laminæ of pyrites for a period of one year in very humid air to a temperature varying from 35 degs. to 45 degs. C. At the beginning, the surface of the pyrites was as brilliant as silver, but at the end of ten to twelve months the pieces on the outside of the lumps commenced to disintegrate and fall to powder. The pieces inside the lumps were, however, as brilliant as at first.

Mr. Fayol also states that, under the same experimental conditions, the action of the atmosphere on pyrites is not so energetic as it is on coal. When gradually heated up to 200 degs. pyrites and coal behaved exactly alike until a temperature of 135 degs. was reached. From this point the temperature of the pyrites remained the same, while the coal powder became hotter until the igniting point was reached.

It is also well-known that in many cases fires frequently occur in

seams which are particularly free from pyrites. The ten-yard coal of South Staffordshire does not contain on an average more than 0·6 to 1 per cent. of pyrites, and yet in spite of all precautions fires break out with unfortunate frequency. Indeed it is questionable whether any district is more subject to such outbreaks than South Staffordshire, and yet the ignitions are confined to one seam containing a small percentage of pyrites, while some of the other seams have large quantities of this impurity. The researches of Prof. Richters afford the most conclusive proof of this point. In the following table he arranged eleven varieties of coal from the Carboniferous system in three classes, according to the degree of their self-inflammability :—

Liability to Spontaneous Ignition.		Pyrites. Per Cent.	Water. Per Cent.	Character of the Coal.
Class I.—Very slight	1	1.13	2.54	Easily friable.
	2	{ From 1.01 to 3.04 }	2.75	Very compact.
	3		3.90	Do.
Class II.—Medium	4	1.20	4.50	Firm, schistose, bright.
	5	1.08	4.55	Hard, but very brittle.
	6	1.15	4.75	Moderately tender.
	7	1.12	4.85	Outwardly very like No. 1.
Class III.—Great	8	1.00	9.01	Moderately tender, schistose.
	9	0.83	5.30	Moderately soft, schistose.
	10	1.35	4.85	Do.
	11	0.84	5.52	Not stated, yielded only 2.5 per cent. of ash. From the same pit as No. 10, but from a different seam, noted for its great self-inflammability.

Especial attention is directed to the fact, also established by the above table, that coals containing a large proportion of water are more subject to self-inflammability than those containing little moisture. The moisture given in the second column is not due to external wetting, but is absorbed from the air and held by the coal. The amount present indicates the power of absorption possessed by the coal both for aqueous vapour and oxygen. This contention is supported by evidence obtained from the thick coal of South Staffordshire, which contains from 8 to 11 per cent. of moisture. Prof. Lewes* states that the researches of Messrs. Cowper, Baker, Dixon, and others have so fully shown the important part which moisture plays in chemical combination, that it is now generally recognized as a factor of importance in actions of this kind. At first, external wetting

* *Journal of the Society of Arts*, vol. xl., page 356.

retards the absorption of oxygen by coal, but the presence of moisture afterwards increases the action of the already absorbed oxygen upon the hydrocarbons of the coal and so causes a serious increase in the heating. In support of such a view he instances the following case :—A ship took in a cargo of coal at a Welsh port, the weather being fine and dry while she was loading at the main hatch, and wet whilst taking in the coal at the after hatch, with the result that the temperature after the first few days was uniformly about 10 degs. higher in the coal that had been loaded wet than in the dry portion of the cargo, spontaneous ignition being the ultimate result.

With reference to the part played by pressure little can be added to what has already been said. If fire be found anywhere it will generally be in cracks and fissures. The writer cannot accept as correct the statement made at the Derby meeting* that solid coal has been known to fire; as, although fire has been got out of large blocks of coal, yet if such pillars are carefully examined they will be found to be fractured. As an instance of this, an experience at Lye Cross pit may be quoted where a fire was detected on the side of a road passing along one edge of a large block of coal. The outbreak took place at a distance of 8 yards from the side of the cross road, and on the fire being dug out, a small fissure, not more than $\frac{1}{8}$ inch wide, was detected and followed into the apparently solid block for a distance of 7 yards. The temperature decreased as the crack was traced and became normal as soon as the really solid coal was reached.

The difference of opinion is solely due to the meaning implied by the expression "solid coal." Mining engineers, in broadly generalizing, usually speak of coal being "in the solid" when it stands in the form of large pillars 40 or 50 yards square, formed by the intersection of narrow roads crossing each other at or about right angles. It is quite possible, and indeed often happens, that these pillars are cracked, and if they are, they cannot be called solid, using that word in its strictly literal meaning. Indeed it would be impossible to account for any fire taking place in solid coal; neither the hydrocarbons or pyrites in the coal could be supplied with oxygen, and as fine coal is absent there is nothing to commence ignition. In the case of unworked pillars, fire may take place for the following reasons :—The load bears unevenly around them and they crack under the heavy crush to which they are subjected; the fine crushed coal is heated by the friction produced and also absorbs oxygen until eventually ignition takes place. The heavier the pressure, the sooner do the pillars heat and fire.

* *Trans. Fed. Inst.*, vol. iv., page 490.

Although the grinding action resulting from pressure introduces a grave element of danger, yet such action entirely fails to account for the fires which take place with frequency in small heaps of coal lying loose on timbering or in those stacked on the surface. The writer knows cases where less than one ton of small coal lying loose on timber settings beneath and over which a fairly strong current of air has been passing has heated to such an extent in three weeks that pieces of it could not be held in the hand. Indeed the heating takes place so rapidly, especially in return airways, that fire frequently breaks out before the heating is detected. Mr. W. F. Clark and the writer, gave a typical, and not uncommon, experience of this in the paper already referred to.*

In seams free from pyrites and in heaps of loose coal no other explanation can be given when fire breaks out, except that it is due to oxidation of the organic constituents of the coal. Both from the scientific evidence quoted and from the experience gained in his mining practice, the writer is strongly of opinion that oxidation plays the principal rôle in promoting spontaneous ignitions, and that most danger is to be feared from its action, as everything met with underground seems to combine to render this agent successful. The absorption of oxygen is favoured by moisture, fine division, absence of light, and especially by increase of temperature, while in proportion to the rapidity of oxidation is the elevation of temperature and consequent risk of ignition.

Conditions favourable to Development.—All coals can be divided into several classes which vary by imperceptible degrees, forming first the class called lignite, second the free-burning bituminous varieties, third the caking coals, and finally anthracite. The changes producing these various types have taken place by the elimination of their gaseous elements, the free-burning varieties containing a much larger proportion of oxygen and volatile matters than the anthracitic ones. Neglecting a few exceptions, it may be given as a general rule that the coals most liable to spontaneous combustion are those which have first departed from the lignitic type. Lignites themselves need not be specially alluded to here, except to say that everyone who has been connected with their working describes them as being more subject to spontaneous ignition than any other known coal. With the exception of a few small deposits, lignites do not exist in Great Britain, but we are rather freely supplied with the succeeding class. The free-burning semi-bituminous coals of South Staffordshire, Warwickshire, and Leicestershire are instances in point. They

* *Trans. Fed. Inst.*, vol. iii., page 48.

all contain a large percentage of oxygen and volatile hydrocarbons, and without doubt are more subject to fires than any other seams in this country.

The pure free-burning coals of Silesia are also very liable to spontaneous combustion, but Mr. Durand states that in the central basin of France the coals most subject to such action are the caking ones. This may be true for the district he alludes to, but it is an exception (and even in this case the coals contain a large proportion of volatile matters amounting in extreme instances to 40 per cent.). On the other hand, Mr. Fayol determined the order of inflammability as (1) lignites, (2) bituminous coals, (3) caking coals, and (4) anthracite.

So far as anthracite is concerned, no instances of spontaneous combustion are on record.

The state of division is of chief importance, the smaller the coal the greater is its power of self-inflammability. Fine coal does not absorb more oxygen than large coal, but as it offers a greater surface to the atmosphere the action takes place with greater rapidity, and consequently the temperature increases quickly. Mr. Fayol proved by experiments that when the size of the particles was 1 centimetre, the powder of lignite, bituminous coal, caking coal, and anthracite ignited at 400 degs. C., but that when the size of the dust-particles was reduced to $\frac{1}{2}$ millimetre combustion took place in the three former classes at 200 degs. C., but not with anthracite. With particles of the last-mentioned size, bituminous coal ignited as low as 150 degs. C., and lignites at 100 degs. C. When in the state of impalpable powder, he was able not only to ignite lignites but also several varieties of the free-burning bituminous coals at a temperature of 100 degs. C. These facts are very significant, as some coal-dusts require such a low temperature to ignite them, and at the same time are so ready to absorb oxygen that spontaneous ignition may take place in a short space of time.

The quality of the coal also exercises its influence. Soft, black, sooty coal is far more liable to fire than that of a harder nature. In several collieries under the writer's charge, the coal is much interfered with by intrusions of basalt, and bands of sooty coal are met with. It almost seems like romancing to say that fires break out in such coal in less than twenty-four hours, but instances are on record where a gateroad has been left apparently safe at 4.30 p.m., and been found on fire at 7 o'clock the following morning. Such cases are surprising, when it is remembered that the overmen are only too well acquainted with the preliminary symptoms of ignition, and know also how liable such coal is to take fire, and con-

sequently examine such places with greater care. To prevent any misunderstanding, it should also be stated that when an outbreak occurs as mentioned above, the existing conditions are usually such as would lead anyone to be on their guard ; for, in addition to the inferior quality of the coal, the air-current is usually warm and moist, and the coal is often under considerable pressure.

In order that combustion may take place, a certain quantity of air must be supplied ; if therefore the supply of air be completely cut off ignition could not occur. The practical difficulty is of course how to completely cut off all air. On the other hand, if air in large quantities can be introduced ignitions could not occur, because as soon as any heating took place the coal would be cooled by the rapid current passing over it.

Prevention.—In the paper Mr. Settle read at the London meeting of the Federated Institution of Mining Engineers,* several fundamental principles are given, which he thinks, should be observed when working coal liable to spontaneous combustion. The writer is prepared to agree with all these, except the last one, but thinks that some qualification is necessary to more than one of the others. The statement to which most exception is taken, is “Do not pass more ventilation through a district than is sufficient to keep the working-places and gob-edges free from gas.” This practically means that the quantity of air circulated should be reduced to the lowest limit, and while such should be the case under certain circumstances, yet the writer believes that the direct opposite is often very successful in preventing fire. It seems established that when coal containing a certain proportion of water or moisture and organic matter is stacked in bulk, in a slightly moist condition, it undergoes a sweating action with the formation of heat, during which the oxy-compounds in the coal become partially decomposed. If the coal be a porous one oxidation proceeds, and, according to the amount of air which permeates the bulk and the length of time which elapses, the temperature of the mass may even continue to rise or gradually cool down. Mr. Thomas is of the opinion that if the temperature of the mass could be kept down during the sweat and until the small quantity of volatile matter had undergone oxidation, there would be little fear of spontaneous combustion occurring afterwards. The only way to cool down the coal is to circulate a vigorous current of air through it. If the quantity of air be reduced, there is always enough oxygen left to oxidize the organic constituents. To more forcibly illustrate this point, the writer may quote an instance of a fire at one of his pits, which is now being dealt with, and

* *Trans. Fed. Inst.*, vol. v., page 10.

which has either been on fire or on the verge of fire for more than six months. The method of dealing with it is to drive roads into the heated portion and to ventilate it as thoroughly as possible. The area so being treated lies between two roads, which are about 35 yards apart, and a specimen of the coal is exhibited showing that it has been subjected to so much heat that the volatile matters have been distilled out of it; the sample resembles a piece of coal which has had one side dipped into a bucket of tar.

The writer thinks that no diversity of opinion should exist on the point whether air should be circulated through the working-places or not, but one should rather differ as to whether it is possible to ventilate a gob thoroughly. The writer here agrees with Mr. Settle, viz., that a gob should not have air passed into it. He would not say: do not ventilate a gob, because it is his opinion that if it were possible to do so, success in preventing outbursts would follow, but the difficulty here is to perfectly ventilate the gob. It is impossible to get sufficient air into any gob, even supposing the roadways are very near together. Prof. Lewes, in discussing the same point applied to coal cargoes, remarks that perfect ventilation is impossible on account of the mass of coal present, and therefore the hold should be battened down, and everything done to prevent imperfect ventilation, but with coal bunkers, on the other hand, on account of free access being obtained both to the top and bottom of the coal, and also the small mass present, perfect ventilation is possible and should be attempted. In several parts of this country it is by no means an uncommon practice to preserve heaps of coal stacked during the slack season by placing, in the mass, wooden perforated pipes, through which air can readily pass into the middle of the mass of coal. The first procedure is to lay them in the bottom, and then as the coal is tipped over them others are added, until the mass is riddled with these conduits. On the Continent such procedure is still more common, and a patent was taken out in 1882 for passing exhaust steam through similar pipes into the centre of the slack-heaps, and it is stated that this method has been very successful.

With respect to removing all fine slack from the gob, everyone is agreed on this point. If there were no fine coal to oxidize, spontaneous combustion is not likely to occur. The entire removal of the coal does not mean that fires would entirely cease, because the shale often met with in the roof is just as liable to ignite as coal. At the Derby meeting, a statement was made that fires could not occur under a white rock roof.* This may be true in one district, but it is decidedly not the case in South

* *Trans. Fed. Inst.*, vol. iv., page 491.

Staffordshire. The roof of the thick coal consists of, first of all, 10 to 12 feet of a white metal, followed by from 20 to 40 yards of sandstone rock, yet fires are common.

Mr. Settle's suggestion for working seams liable to spontaneous combustion in panels, is supported by all the evidence obtained in working the ten yards coal in South Staffordshire. The oldest method, and one most largely employed, is identical with the one he sketched. The side of work of South Staffordshire is really a small panel, which is kept separate from adjoining ones, and is always sealed off when finished, whether it has taken fire or not. Temporary stoppings are always erected before the side of work is fully opened. The general practice is, however, against erecting these stoppings of brick and mortar. Under the influence of pressure both from the roof and sides, walls of masonry are very liable to crack, and of course as soon as they do so they are completely worthless. The most successful way in this district, is first of all to cut a groove about 2 feet wide into the floor, sides, and roof, until perfectly solid coal is reached. While the panel is being worked a road has to be kept into it, and four chocks or cogs are built, two on each side of the groove, and two on each side of the road. The groove itself is filled with sand, which is well rammed. Under the influence of the pressure these cogs get solid before the side of work is finished, and when all the coal has been got out the centre part through which tubs pass is filled in with packing, and the sand-dam completed.

It has not been found necessary to leave larger ribs in ordinary working than about 10 yards broad. The fifty yards of coal that Mr. Settle states were left in the Bullhurst seam cannot be considered an excessive amount under the exceptional conditions which he illustrated, but in this district nothing like such a width has ever been left except under most abnormal circumstances.

It is very necessary in longwall workings that the gob should be well and completely stowed, which not only helps to prevent fires but often keeps them isolated if they should break out. It also allows the coal to be completely won, and diminishes the sinking of the ground. In working the thick seams of France, which are so liable to spontaneous combustion, complete stowing is carried out. The packing-material is in many cases obtained from quarries on the surface and is then sent underground. The seams are highly inclined, in some cases nearly vertical, and the method of working is taking away thin slices, which are removed, preferably from top to bottom. All empty spaces are filled immediately the coal is

removed, and the winning is very complete, everything being brought away, even to the shales, capable of undergoing spontaneous combustion.

Rapid working often prevents heating, as the winning of a given district goes on faster than the coal can spontaneously ignite. A slow working favours fire in allowing broken coal in communication with air-ways to obtain sufficient air to support slow combustion. The blocks of coal formed by the intersection of the roadways should be as large as possible, as the subdivision into small pillars favours breakage and ignition. If the gob packing is of a rich earthy character, it becomes compressed and prevents fires spreading. Good and complete packing allows one to avoid and limit fires already in existence.

It is important to watch carefully for the commencement of fires, and attack them at once. As a temporary method, any fissures in the sides of the roads should be carefully filled in with clay, but this does not last long, as it rapidly dries and cracks. If the coal begins to heat, a very active ventilation should be first tried. This has been successful in many cases. It should be distinctly understood that the writer's opinion is not to use a rapid current of air when fire has broken out because, in such a case, it would only increase the danger; but until fire really breaks out, cool air does good. A small fire is best extinguished at once by water, the place got at, and the burnt and broken coal removed. As far as possible, fires are best attacked from above. In many cases, the writer has driven roads in the rock above the coal, and then put down boreholes into the burning mass and applied water on it, thus drowning the fire. This has been very effective, especially in the thick coal. If the fire has got a considerable hold, the only method is to barricade and dam it off, and to completely intercept the access of air. In those rare cases where the fire is too great for dams, the only resource is to hermetically close the mouths of the shafts and isolate the whole mine. After the lapse of a certain time, which may vary from six to eight weeks, or even three months, the pits may be again opened.

When a district is dammed off the combustion of the coal forms several gases, the principal one of which is carbonic acid. This gas will not support combustion, and consequently puts the fire out. Carbonic acid gas is naturally formed by a fire, and it has therefore occurred to engineers that if that gas were artificially formed and passed into the burning area, the fire would be more rapidly put out. This procedure has been locally tried in South Staffordshire by several engineers, and always with success. When it is necessary that the pit-shafts should be sealed up, carbonic acid gas should always be passed into the mine. The

most notable instance of this procedure was the extinguishing of the fire at Winnstay colliery. Even with sealing up the shafts and passing in carbonic acid gas, some fires cannot be extinguished, and there only then remains the heroic measure of flooding the mine, which should only be done when every other plan has failed—for the remedy is nearly as bad as the disease.

Conclusions.—The chief points which the writer has attempted to make clear are :—

1. That iron pyrites plays a very unimportant part in the spontaneous combustion of coal, so far as direct action is concerned, but that it may materially assist by disintegrating the coal and by producing a slight rise in temperature. When it exists in the form of bright brassy lumps and veins little danger is to be apprehended, but the maximum effect is exerted when it occurs in the form of a dark amorphous powder finely disseminated through the coal.

2. That coal never fires in the solid. If combustion commences in a large pillar this pillar will be found to be fissured.

3. That although pressure on pillars greatly increases the danger of spontaneous combustion, yet it is doubtful whether this action alone would start a fire.

4. That oxidation of the organic constituents of the coal is the main cause of underground fires.

5. That the coals most liable to spontaneous combustion are the highly oxygenized semi-bituminous varieties containing a large proportion of moisture.

6. That the only method of prevention is to circulate as large a current of air as possible through the workings, to carefully remove all the fine coal from the mine, to exclude as completely as possible all air from the gob, and from heaps of shale, etc., in pillar-workings, and in longwall workings to stow the gob carefully and completely, keeping the pack-walls continuous.

Bibliography.—Fuller information may be obtained from the following memoirs :—

"The Weathering and Spontaneous Combustion of Coal," Dr. Percy, *Metallurgy, Fuel, etc.*, pages 289-300; "Fires in Mines, their Causes and Means of Preventing them," R. P. Rothwell, *Trans. Am. Inst. Min. Eng.*, vol. iv., page 54; "Prevention of Spontaneous Combustion of Coal at Sea," T. W. Bunning, *Trans. N. E. Inst. Min. Eng.*, vol. xxv., page 107; "Coal-mine Gases and Ventilation," J. W. Thomas, pages 241-253; "Incendies dans les Houillères, Procédés employés pour les Prévenir et les Éteindre," M. Nesterowsky, *Bull. Soc. Ind. Min. de St. Etienne*, vol. vii. (2nd series), page 839; "Études sur l'Altération et la Combustion Spontanée de la Houille

exposée à l'Air," H. Fayol, *Bull. Soc. Ind. Min.*, vol. viii. (2nd series), page 487; "Cause and Prevention of Underground Fires," T. Bertram, *Jour. Brit. Soc. Min. Students*, vol. vi., page 184; "Note sur les Incendies dans les Houillères," M. Durand, *Bull. Soc. Ind. Min.*, vol. xii. (2nd series), page 43; "The Spontaneous Combustion of Coal," H. W. Hughes, *Trans. S. Staffs. Inst. Min. Eng.*, vol. xi., page 33; "Pit Fires: a Consideration of Careful Special Packing as a Preventive," S. Spruce, *Trans. N. Staffs. Inst. Min. Eng.*, vol. viii., page 38; "The Spontaneous Ignition of Coal and its Prevention," V. B. Lewes, *Jour. Soc. Arts*, vol. xl., page 351.

The CHAIRMAN moved a vote of thanks to Mr. Hughes for his valuable and interesting paper, which was cordially adopted, and the discussion was adjourned, to a Special General Meeting to be held on July 3rd, 1893.

**SOUTH STAFFORDSHIRE AND EAST WORCESTERSHIRE
INSTITUTE OF MINING ENGINEERS.**

SPECIAL GENERAL MEETING,

HELD IN THE MASON COLLEGE, BIRMINGHAM, JULY 3RD, 1893.

MR. W. F. CLARK, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The PRESIDENT returned his thanks to the members for the letter of condolence forwarded by the Institute on the occasion of recent domestic troubles.

**DISCUSSION UPON MR. H. W. HUGHES' PAPER ON "THE
SPONTANEOUS COMBUSTION OF COAL."***

MR. BENNETT H. BROUGH stated that on visiting the Kimberley diamond mines last summer he was struck with the obvious evidences of the influence of iron pyrites in bringing about the spontaneous combustion of black shale. Among the rocks passed through by the pipes of diamond-bearing rock are from 200 to 300 feet of the characteristic shales of the country. The black shales contain much iron pyrites, and in the open excavations of the Kimberley, Bultfontein, and Dutoitspan mines have ignited spontaneously and continued burning for years, giving off a strong sulphurous odour that can be smelt for many miles. The burning shale is, however, not a menace to the system of underground mining now adopted, as the downcast shaft is situated at a considerable distance from the burning shale and at a much higher elevation. Consequently, no trace of the fumes from the shale burning in the open quarry is noticeable underground. Though this fact in some measure supports the pyrites theory of spontaneous combustion, it should be borne in mind that the spontaneous ignition of the shale is met with only in the open quarry and in the waste-heaps. Mr. Hughes does not appear to have sufficiently

* *Trans. Fed. Inst.*, vol. v., page 392.

dwelt upon the liability of brown coal or lignite to spontaneous ignition. In the working places in brown coal-mines, spontaneous ignition occurs with very great facility, and there are but few such mines in Central Europe without fires raging underground. Fortunately, by hermetically sealing-up such places the fire is soon extinguished, and the place may be reopened in three months' time. Even in factories in which brown coal briquettes are made, explosions due to the spontaneous ignition of the coal are of frequent occurrence. The dust is in a fine state of division, and an explosion occurs when this dust spontaneously ignited extends over a large area with access of air. A study of the spontaneous ignition of brown coal appears to support the view that the absorption of oxygen is the primary cause of this phenomenon. The coal is oxidized or weathered with great rapidity, and carbonic anhydride and water are formed. The decomposition of iron pyrites is of subordinate importance, inasmuch as it is effected only in the presence of moisture, and is accompanied by a development of heat which, as is well known, increases the absorption of oxygen. The state of division of the coal, as Mr. Hughes points out, is an important factor. Small coal absorbs oxygen with greater avidity than does lump coal, and consequently becomes more heated and weathers more rapidly. Experience shows that fires occur most frequently where large quantities of coal-dust are left in the workings, or where the pillars are greatly fissured by pressure. In these fissures, a quantity of coal-dust is produced, which ignites by absorbing oxygen. It seems incredible that the pillars should be heated sufficiently by pressure to ignite the dust.

Mr. H. G. GRAVES wrote that at the last meeting of the Federated Institution of Mining Engineers in London, considerable confusion appeared to have arisen over the term "solid coal" and over the proper use of ventilation, but the clear account then given by Mr. Hughes ought to set both these matters at rest. In solid coal (using the word solid in its general acceptation as meaning unfractured and not in the more limited mining sense as unworked or unbroken coal), there can be no combustion, since the air has practically no surface on which to act. When the pillars yield under the weight of the overburden, they crack and are no longer solid. Air can then enter the cracks and the oxidation together with the friction due to the movement may cause fire. That pressure by itself may be sufficient to give rise to spontaneous combustion can easily be seen from the following rough calculation. Say an 8 yards pillar of coal at a depth of 100 yards settles 6 inches under a load of 10,000 tons, then 5,000 foot-tons of work will be done. This is equivalent to 15,000 heat units, which would be capable of heating 150 lbs. of coal 400 degs. Fahr. if the

heat were localized, as some of it might be. This approximate calculation is only put forward as a slight addition to the pressure theory, for the writer thinks that oxidation is the most potent factor in the phenomenon of spontaneous combustion. No one, of course, upholds the idea that the ventilation should be good after the fire breaks out, but before that crisis, it seems best from all points of view to have a good air-current on account of its cooling effects. It is not possible to exclude all the air from a colliery, though it may be excluded from a ship's hold. In the latter case no air or plenty of air seem equally good. A farmer, too, when a stack of hay heats, will cut through it to cool it, and, in this connexion, it may be noticed that the first patent specification for the Capell fan described its use for cooling stacks. The main point is to cool the coal, and especially the small coal, concurrently with the oxidation. To avoid combustion therefore, crushing must be avoided, and small coal (especially when freshly broken), should not be allowed to accumulate and become hot.

Mr. W. B. SCOTT said it occurred to him that their Institute could with advantage discuss certain points in the subject before them, viz., what was the cause of spontaneous combustion; how to prevent it, and how to extinguish it when it had gained ground? It appeared to him they should first enquire what class of coal was most liable to spontaneous combustion. Mr. Hughes had given them the result of Prof. Richter's researches, and he thought they might consider that anthracite was not liable to spontaneous combustion; that certain classes of coal were more liable than others; and that fires had occurred in every coal except the brooch seam. Then arose the question, what was the cause? In his summary of points dealt with, Mr. Hughes stated that iron pyrites played a very unimportant part in the spontaneous combustion of coal, and with this he was very much inclined to agree. As to No. 2 point, the writer of the paper contended that coal never fired in the solid; and he (Mr. Scott) thought they might concur that a solid lump of coal would not fire, and that if combustion did commence in a large pillar, that pillar would be found to be fissured. The third statement in Mr. Hughes' summary was that although pressure on pillars greatly increased the danger of spontaneous combustion, yet it was doubtful whether that action alone would start a fire. This he could not quite follow, because, under certain conditions, if the pressure produced the necessary amount of heat, a fire would be set up. He might, however, observe that he thoroughly concurred in the following point, and was of opinion that the outcome of that discussion would be that oxidation of the organic constituents was the main cause of underground fires. Such a rapid organic change was

set up that the heat increased and the fire broke out. This had been laid down by authorities for some time. Given a handful of pure carbon, and a stream of oxygen poured upon it, the heap would burst at once into combustion. With respect to the allusion in No. 5, he should like to ask Mr. Hughes whether the "moisture" is the cause or the effect? He was inclined to think the latter. The concluding point was as to the method of prevention; and whilst agreeing as to some of the suggestions made, he knew of an instance of a colliery in Cannock Chase where complete stowing in the gob did not prevent a fire breaking out. They might be sure that fires would break out in the gob, even when they were carefully stowed.

Mr. W. B. COLLIS believed, from the result of his observations, extending over more than thirty years, that the cause of spontaneous combustion was the rapid absorption of oxygen by the finely divided particles of coal. They might find it in the finely divided particles existing in the coal itself, which was otherwise solid, or they might find it in the small particles lying in heaps of slack cast aside—sometimes in the gob itself, and also in proximity of faults and disturbances—but he thought in every case the real cause was the same. It was rapid absorption of oxygen by the finely divided particles of carbon in the coal. They found sometimes, when the coal had been affected by water, that that absorption took place still more rapidly. Gob-fires presented themselves with great suddenness and rapidity, and it had occurred to him whether, in such cases, the moisture was communicated from particle to particle, and thus assisted in the rapid development of heat and fire. They had gone nearly as far as they could, by experiment and by knowledge of chemistry, in the discovery of the real cause of spontaneous combustion. He did not think anything had, so far, been said in regard to the method to be employed in dealing with it, except Mr. Hughes' suggestion of ventilation. No doubt it was very desirable to bring a stream of air into a place where fire was breeding, and if possible to cool it down, and so minimize the danger, and possibly destroy it. They were not, of course, always able to do that. They came then to the consideration of what was the next best thing to be done. This was to seal it up—to exclude the air and destroy the fire by the absence of oxygen. They brought about, in this manner, an atmosphere largely composed of carbonic acid gas, which would not support, but destroyed, combustion. Other methods were employed which were worthy of consideration. He had used a plan of manufacturing carbonic acid gas. At his colliery they set up at one time a small manufactory very close to the place. They got some large casks, capable of holding

10 cwts. of fluid each, and took them to within a short distance of the place. They put finely broken up limestone into these casks ; then poured hydrochloric acid upon the broken limestone, and carbonic acid was given off. By having two large casks they had a sufficient supply, and by that means kept the enemy at bay. He did not know that that had been done before on the small scale to which he referred. They sometimes made large quantities of carbonic gas and poured it down the shaft. He knew, however, of no royal road to get rid of underground fires. They were always a source of great trouble, labour, and anxiety. Spontaneous combustion was an insidious enemy, which had carefully to be watched, and mines should be so worked as to be exposed as little as possible to that enemy.

Mr. ISAAC MEACHEM, Jun., said one of the earliest experiments he made in connexion with fire was about fifteen years ago. At the Granville colliery, Old Hill, they were troubled a great deal with fire in the face of work. They determined to increase their quantity of air. They increased the quantity of air travelling round the face of work, with the result that from that time they never had any more fire in the face of work in that pit.

Mr. W. J. HAYWARD observed it was well known that the new mine coal at West Bromwich contained a large quantity of pyrites, yet he had never known a single case of gob-fire in that seam. Mr. Hughes laid great stress upon the oxidation of coal, but he (Mr. Hayward) attached as much importance to pressure as to the absorption of oxygen. The former was, in his opinion, a prolific source of fire, and he had then in his mind at least two cases where it was evident that pressure had been the cause of ignition. With regard to prevention, the best method was the circulation of a large quantity of air until combustion actually occurred when, of course, such ventilation must cease. Referring to the sixth point in the paper under notice, he might remark that if they could bring to bank the great quantity of fine dust which at present was cast into the gob they would have fewer gob-fires. More attention might, perhaps, be paid to the system of cogging, and if this were made continuous, where practicable, it would tend to decrease the number of fires.

Mr. F. G. MEACHEM said he was sure every one present must feel greatly indebted to Mr. Hughes for bringing the subject forward in so able a manner. As for the causes of combustion, they must, in the first place, agree with Dud Dudley, who in his *Metallum Martis* (which was published in 1665) said it was the small coals which were left behind because they were of no value that fired—but Dud Dudley did not tell

them how these small coals first commenced to heat. He was very much inclined to believe the fourth clause in Mr. Hughes' summing up. At the same time, the study of prevention was what had, up to the present, occupied most of his attention. Taking as a starting-point, the acknowledged fact that it was the small coals that fired, at Hamstead colliery they had always made a point of clearing them out, and to make sure of this, when they were opening a panel, say 100 yards in length, they only drove 96 yards. They left the 4 yards to be side-barred off. The effect of this was to take out all the breaks in the rib and leave it solid, and the foot of the rib was easier cleared of fine slack to the rock below. They had invariably found that the coal was broken alongside roads for 6 to 8 feet even when driven in the solid, and it was mostly in these breaks that the fires occurred. With respect to fires in the solid, they had had many cases, and they had found that they mostly occurred in old geological time breaks. These breaks and slip things appeared to have been opened and then filled with white calcite intermixed with pyrites. In a case they had only a few weeks ago, the road was driven in the solid coal, the nearest workings being 400 yards away. Fire-stink was detected and search was made. A small head was driven off the side of the main road, and in 9 feet, three open recent breaks were passed, full of fine dust but no fire. At 12 feet from the side of the road, an old break was met with containing calcite and pyrites, from which smoke was issuing. This was followed in an oblique direction to the left, and a few feet farther red-hot coal was cut out. The break was about 3 or 4 inches wide, and the coal was on fire about 3 inches into the solid on either side. This was cleared out, and the place was now cool and safe. He would specially point this out as only one of many instances, and in cases of suspected fires and many breaks being visible, the deputies regularly said to the men "start in that white thing." As to the particular action of that calcite and pyrites he did not, at present, know enough about it to speak with certainty, but he hoped at some future time to be able to give more information. Replying to the chairman, Mr. Meachem added that most of the fires which occurred in the solid were started in these old geological breaks, although there were newer breaks close about, and this, he thought, showed that the older breaks filled with calcite were more susceptible and ready to fire upon the least movement that took place in the coal surrounding the road.

Mr. GRAZEBROOK gave an instance of a sudden outbreak of fire in a mine under the Rowley Hills. At 2 p.m. he carefully examined the road, which was subsequently examined by the overman and others, and at

5 p.m. they found a fire had broken out in a cog above the road. They saw no sign whatever of fire at 2 p.m., and at 5 p.m. they had to put in a dam as the fire had got such complete hold of the road.

Mr. H. W. HUGHES, in reply, alluded, in the first place, to what had been said on the subject of pressure, and held to his opinion that alone it would not start a fire. As to prevention, he repeated that the proper thing to do, as seemed to be admitted, was to put in as much air as possible until fire broke out and then to stop it. He questioned very much whether there was any satisfactory method of dealing with an outbreak of fire except that of damming-up the district and keeping the air from getting to it.

On the motion of the PRESIDENT, seconded by Mr. SCOTT, cordial thanks were accorded to Mr. Hughes for his paper.

Mr. E. J. BAILEY then read the following "Description of the South Dyffryn and Abercanaid Collieries":—

DESCRIPTION OF THE SOUTH DYFFRYN AND ABERCANAID COLLIERIES.

By E. J. BAILEY.

SOUTH DYFFRYN COLLIERY.

There are three shafts—two winding and one pumping, called the Chertsey, Velocity, and Monte shafts respectively. The Chertsey shaft is 630 feet deep and is down to the 9 feet seam, where the pit-bottom and a considerable distance of road has been secured by brickwork. The arching at the pit-bottom is 18 feet in diameter; other arching is 13 feet in diameter. The pit-bottom, engine-house, screens, pit-top, shops, offices, and sidings are lighted by electric incandescent lamps from a dynamo and engine on the surface. The Velocity shaft has lately been sunk to a depth of 180 feet below the 9 feet seam to the 5 feet 6 inches and lower 4 feet seams, which are now being opened out.

Both the Chertsey and Velocity shafts have winding-engines and head-gear. The engines have cylinders 30 inches in diameter and 5 feet stroke, and are fitted with slide-valves of an improved type. The Velocity winding-engine is also fitted with automatic reversing gear, constructed by a French engineering firm. The Chertsey winding-engine is supplied with steam from four Cornish single-flued boilers 30 feet long by 6 feet in diameter at a working pressure of 60 lbs. per square inch. The Velocity winding-engine is supplied with steam from four boilers at a pressure of 80 lbs. per square inch, of the double-flued Lancashire type, and fitted with Procter self-acting stokers.

The Monte pumping-shaft is fitted with three 22 inches diameter plunger-lifts, worked by a vertical Cornish engine having a cylinder 85 inches in diameter and 9 feet stroke. This engine is fitted with the Hathorne Davey differential gear in place of the old handles and tappits, and also with a St. John piston-ring. These improvements have greatly reduced the cost of working, and have been the means of reducing the speed and consequent wear and tear of pumps and machinery.

There are seven underground hauling-engines and twelve pumping-engines, all worked by compressed air. The air-compressors were designed by the late Mr. Brunel, the great engineer, and were used by him for

working the pneumatic railway in Cornwall. They were afterwards purchased by the Plymouth Co. for blowing air at the Dyffryn and Plymouth blast-furnaces, and were then fitted with blowing cylinders 100 inches in diameter. The engines have cylinders 45 inches in diameter and 7 feet stroke, and are condensing. Two air-compressing cylinders 42 inches in diameter have replaced the old blowing ones, and the engines have been coupled together on one shaft with fly-wheel. For some years they have supplied the hauling and pumping-engines, at a steam pressure of 45 lbs. per square inch, and have given an average air-pressure underground of 30 lbs. per square inch. Last year, owing to the condition of the steam cylinders, new ones were ordered in case of future mishap; and in order that the underground pumps may be kept going in case these cylinders should have to be changed, a new pair of compound condensing-engines with cylinders 30 inches in diameter have been erected. The North Dyffryn pumping and ventilating-plant comprises a Waddle fan 40 feet in diameter, fitted with two engines for alternate working. The pumping plant is held in readiness to assist the Monte pumping-engines during very wet and stormy weather, the North Dyffryn shaft being situated on the crop of the Monte shaft.

ABERCANAID COLLIERY.

The underground electric motor is placed about 1,200 yards from the generating station. The electric plant consists of a 40 horse-power compound engine with cylinders of 13 inches and 21 inches diameter and 24 inches stroke, working at 96 revolutions per minute. This engine drives direct by belt a dynamo which is built on a wrought-iron girder bed-plate. It is compound-wound, and is capable of giving 180 ampères at 500 volts pressure when running at 550 revolutions per minute. The conducting cable is carried down the downcast shaft and under the road to the hauling-engines, it is 2,800 yards long, and is specially constructed to resist falls of roof, etc. The coal is brought to the winding-shaft bottom along a main level from the electric haulage-engine by an endless-rope worked by an engine fixed upon the surface. The electric engine draws the coal from three roads—one to the rise, one level, and one to the dip. It is fitted with two drums $3\frac{1}{2}$ feet in diameter and 12 inches wide, and works the haulage on the main-and-tail-rope system. This plant is now drawing 650 tons of coal per day from the workings to the endless rope parting. The dip road has a gradient of 1 in 9, and ten trams are pulled up this road with a length of 400 yards, the weight of trams and coal averaging about 18 tons. A small fan, ventilating a heading which is

being driven from the 5 feet 6 inches to the 9 feet seam, is also worked by electricity (capable of giving 15,000 cubic feet of air per minute).

The lighting dynamo supplies lights for the roads and streets in Abercanaid village, and also lights the engine-houses, pit-tops, shops, and sidings; the main road underground and the pit-bottom are also lighted by it. The dynamo is driven by a 12 horse-power Marshall condensing engine, and is capable of lighting 300 incandescent 16 candle-power lights.

The output of coal from the South Dyffryn colliery last year was 233,239 tons, and from Abercanaid colliery 224,425 tons, making a total of 468,164 tons.

A vote of thanks was unanimously accorded to Mr. Bailey for his paper.

**NORTH STAFFORDSHIRE INSTITUTE OF MINING AND
MECHANICAL ENGINEERS.**

**GENERAL MEETING,
HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT,
MARCH 20TH, 1893.**

MR. ROBERT H. COLE, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentlemen, having been previously nominated, were elected :—

ORDINARY MEMBERS—

Mr. ARTHUR DEAN, Colliery Proprietor, Burslem.
Mr. SAMUEL WEBSTER DEAN, Colliery Proprietor, Burslem.

STUDENT—

Mr. OLIVER BROMLEY, Florence Colliery, Longton.

Mr. W. M. MORDEY read the following notes on “Electric Lighting and Transmission of Power” :—

ELECTRIC LIGHTING AND TRANSMISSION OF POWER.

By W. M. MORDEY.

Electricity is a means employed for the transmission of energy and for enabling the energy transmitted to be dissipated in the form of heat or in any other required form at any required places.

Volt is the name given to the practical unit of electromotive force, which would cause a current of one ampère to flow against the resistance of one ohm. An ohm is the unit of electric resistance, and an ampère the unit of electric current or quantity.

The watt is the unit of power, represented by 44·2 foot-pounds per minute, and 746 watts are equivalent to 1 horse-power. A kilo-watt, or 1,000 watts, is the equivalent of about $1\frac{1}{3}$ horse-power or 44,000 foot-pounds per minute; and a kilo-watt for an hour is the Board of Trade unit of electric energy. He thought that sooner or later it would be recognized as convenient to abolish the British units of measurement and to use the metric system based upon absolute quantities.

Energy was convertible and might appear in many forms. There was a loss in the fire-grate of a boiler where the coal was burnt. A portion of the heat was transferred to the water, and the energy took another form. It was transmitted along the steam-pipes to the engine, where it assumed the form of mechanical energy, and by means of a dynamo mechanical energy was converted into electrical energy. The electrical energy was transmitted along a wire to the lamp (if it was required to be used for lighting purposes), where the energy appeared in the form of heat and rendered the carbon-filament incandescent and luminous. A good light and little heat was produced in the electric lamp. The problem of producing light without heat had most nearly been solved by the glow-worm. It only remained that we should do likewise, and thus reduce the demand for coal.

One heard a great deal about systems of electric light and distribution, but they were all very much alike. There was no best system any more than there was a best steam-engine. An engine suited for one purpose might be unsuited for another, so that in electrical systems of generation or distribution of power one had to consider first the conditions, and then apply the method that was more particularly suitable to those conditions.

It was a very easy thing to measure electrical quantities. One of the causes of the advance made in electrical distribution arose from the fact that engineers were able to measure and locate the losses, and arrive at economical conditions.

Referring to the various systems, it was stated that the simple-parallel constant-pressure system was commonly used for house-lighting, where the distance to be traversed by the conductors was small. The three-wire parallel system was of the same character as the last-named, but was adapted for larger areas; and, in fact, was effective for a distance of about $\frac{3}{4}$ mile, though with difficulty.

The Electric Lighting Act of 1882 was, no doubt, framed to prevent people getting and abusing monopolies. This Act imposed such onerous conditions that (for a time) it effectually checked commercial development; but in 1886 some of the limitations were removed, and at the same time it became possible by the development of the alternate current system to distribute electricity over thinly-populated areas, where it would not have been commercially profitable to apply it under the old system. In electric lighting they had by this system succeeded in getting over a long distance by a small conductor, and it was the overcoming of difficulties in this respect that had caused the great development which had taken place in electrical applications.

For domestic work there must be low-pressure, and for long distances there must be high-pressure. The difficulty of combining these two discordances had been solved by the alternating-current system. With an alternator a current of high-pressure could be generated and transmitted a great distance by small conductors, and at the other end it could be transformed or converted to a lower pressure suited to its direct application for lighting.

The cost of electricity varied from $4\frac{1}{2}$ d. per Board of Trade unit at Newcastle, where it was the lowest, to 9d. or 10d. at other places; the average cost being 6d. per unit, which was equal to gas at 3s. per thousand cubic feet.

He was not an opponent of gas, and it was wrong to suppose it would ever be done away with. Coal could be more economically used by being converted into gas at a central works than by being burnt in innumerable little coal-fires. The tendency of the future would be to displace coal-fires and use more gas for heating and cooking, making a special heating-gas rather than a lighting-gas. Dr. Tidy, in his *Modern Chemistry*, said that for the same amount of light, gas gave off twenty times as much heat as an electric lamp, and wax candles gave off twenty-

seven times as much. The electric lamp was quite free from the objections that applied to gas, which produced large quantities of carbonic acid and other poisonous waste-products. Gas engines also would be improved, especially in size, and would be largely used for electric lighting and other work.

It had been asserted that one of the difficulties in the way of the application of high-tension working by alternating currents was that alternating currents were not applicable for transmission of power. He was not an advocate particularly of alternate-current working, though his position imposed upon him the responsibility of designing all kinds of apparatus. He was indifferent as to what system was used, so long as it was suitable to the special circumstances. He was glad to say that, although hitherto power-transmission by direct currents had been easier than by alternating currents, the difficulties in this respect had been to a great extent overcome, and all the large power-transmission work with which he was acquainted was now being done by alternating currents. In Switzerland and the United States, alternating currents were being used in preference to direct currents.

Mr. FARAM said some people considered 10 units of electricity were equal to 825 feet of gas, and others put it as high as 1,200 feet. What was the real proportion?

Mr. MORDEY said that the best way to answer this question was to calculate from known data, and find what light could be obtained from a gas unit of 1,000 cubic feet, and from an electric unit of 1 kilowatt-hour. An ordinary 5 feet gas-burner may be taken as giving 10 candle-power (under good conditions it gives more, and under ordinary domestic conditions it gives less). An ordinary electric lamp working at 30 watts gives 10 candle-power. In a few months, on the expiry of certain patents better lamps will be in use, and 10 candle lamps will then require only 25 watts, but the higher figure may be taken at present. From these data, it will be seen that a gas unit and an electric unit give the following amounts of light. With gas, 1,000 cubic feet will supply a 10 candle-power light for 200 hours, or 2,000 candle-hours. With electricity, 1,000 watt-hours (or 1 unit) will supply a 10 candle-power lamp for 33·3 hours or 333 candle-hours. Therefore, 1,000 cubic feet of gas, so far as light-giving is concerned, is equal to 6 electric units. This direct comparison between the cost of light by gas and by electricity,

shows that they are equal in this respect, when gas is 3s. per 1,000 cubic feet, and electricity is 6d. per unit. At these prices, either agent will produce 55½ candle-hours for one penny.

Mr. JOEL SETTLE said that if electricity represented gas at 2s. 9d. per 1,000 cubic feet, there could be no comparison which would be the best; as the gas company would have, over and above the sale of gas, all the bye-products as a clear profit.

Mr. MORDEY supposed if the gas company charged 2s. 9d., that was the price at which they could make a profit. But electricity, even at a higher price than gas, was freely sold, and the electric stations were being pressed to extend. He believed if they charged even more than they did at present, the increased use of electricity would still go on. People who valued health would have the electric light, unless it was charged at an outrageous price. But he was satisfied that, on a large scale, electric light could be supplied as cheaply as gas.

Mr. E. B. WAIN enquired whether there was any loss of power in transforming from a high-tension to a low-tension current, and also whether it was a fact that one of the public vestries supplied electricity which was competing as regarded cost with gas?

Mr. MORDEY observed that there were losses, in connexion with the transforming from high-tension to low-tension, from 2 to 4 per cent. at full load, but it was nothing like so great as the loss of money and energy would be in having large copper mains for the low-tension system. It was true that the St. Pancras Vestry charged 6d. per unit for light at night and 3d. per unit by day; their machinery stood idle during a great part of the day, and the desire was to encourage the use of it.

Mr. E. B. WAIN asked if that vestry could work at a profit?

Mr. MORDEY said the result of the first year's working showed a profit. The early installations were costly, but the results obtained with modern apparatus were satisfactory. At Newcastle-upon-Tyne, there were two stations: at one station the electricity was distributed over a thinly-lighted area; the charge was 4½d. per unit—the lowest price in England—and the result even of the first year's working was profitable. The unit cost 3d., and they sold it for 4½d. There was no reason why, in a manufacturing town where coal was cheap, electricity should not be produced at 3d. per unit.

On the motion of Mr. J. STRICK, seconded by Mr. E. B. WAIN, a vote of thanks was accorded to Mr. Mordey for his paper.

NORTH STAFFORDSHIRE INSTITUTE OF MINING AND
MECHANICAL ENGINEERS.

GENERAL MEETING,

HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT,
APRIL 10TH, 1893.

MR. ROBERT H. COLE, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

The following gentleman, having been previously nominated, was
elected :—

STUDENT—

MR. JOHN T. BOOTH, Mining Student, Longstile, Talke, near Stoke-upon-Trent.

DISCUSSION UPON MR. E. B. WAIN'S PAPER ON "THE
LONGWALL METHOD OF WORKING AS APPLIED TO
SEAMS OF MODERATE INCLINATION IN NORTH
STAFFORDSHIRE."*

MR. JOEL SETTLE said that so long as the coal was worked in a straight face and proper manner it worked well, and if they were working longwall it must not be done in an half-and-half manner. If they did not insert sufficient packs at proper distances, and put in chocks, there was no doubt they would suffer very much, as the roof would tend to break down when not supported. There was one thing in the paper which he would like to have heard more about, and that was as to the strata breaking at right angles to the dip of the mine. Assuming that this might be taken at right angles, the support of either a railway or a canal would require a larger pillar to be left on the upper than on the dip side. Mr. Wain had given particulars of various mines. In a seam working at

* *Trans. Fed. Inst.*, vol. iv., page 24.

a depth of 200 yards, the angle was 5 degs. less than a line drawn at right angles to the dip of the mine. At a depth of 280 yards the break was exactly at right angles to the dip, but at 470 yards it was 6 degs. more than a line drawn at right angles to the dip. He had observed in the ten-feet, which had a strong rock roof, and ran through the North Staffordshire district, that in all cases where it had been worked on proper pillar-and-stall principle and a regular dip, this seam always broke at right angles to the dip of the mine. If there was any variation from this, it was due to different conditions of the mine.

Mr. W. H. WAIN asked whether there was any necessity to "rob" the pack to get the roof to break properly?

Mr. E. B. WAIN replied that there was not.

Mr. W. H. WAIN said the difficulty found in the Bullhurst seam was in getting the roof to weight properly, but there was no difficulty here. Mr. E. B. Wain called particular attention to the line of the face. The line of the face dipped at an angle of about 1 in 25, and they put the packs at right angles to the line of the face. It struck him in reading the paper as being contrary to his own experience, they got the packs to stand better at right angles to the line of dip; when the weight came on, the tendency was not to slip at right angles to the line of face, but to the dip. There was a certain amount of gravitation brought into play, causing breaks in the line of full dip, that caused the packs to throw over into the gateways or waste, nipping in the top or bulging in the middle, especially if there had been bad packing.

Mr. J. R. HAINES asked the cost of timbering on this system, and whether the line of face was worked practically with the line of cleavage?

Mr. E. B. WAIN said it was worked irrespective of the line of cleavage.

Mr. HAINES observed that that being so they must have the right end face considerably up. Was there any difficulty in getting loaded wagons out of the other side of the stall? Then there was the question of timbering. One would have thought the transverse method would have been better than Mr. Wain's system. They had three rows of props to the working-face, and bars in the waste as well, which was a little contrary to the method of timbering in practice in North Staffordshire.

Mr. E. B. WAIN said, respecting the angle of the dip mentioned by Mr. Settle, he found in practice that the deeper the seam was working, irrespective of the angle of the dip (so long as it was a dip of moderate inclination) the angle of the break varied, and got nearer to a right angle as the seam got deeper. It seemed to be progressive, and the more strata

there were above, the nearer would be the tendency of the roof to break in a vertical direction. As to the size of packs, that was a question to which he had given careful attention; the packs shown in Fig. 1, Plate I., were 5 yards on the top side of the level, and 4 yards in Fig. 4, Plate II.

Mr. JOHN HEATH said they were shown as three-yard packs on the plans.

Mr. E. B. WAIN said there were no three-yard packs, except in the stall face. In practice he had found where the packs were well-built with cross walls at right angles, at the regular distances of $4\frac{1}{2}$ feet, that they were quite sufficient for all practical purposes. In the case of the four-yard packs it was perhaps a case of expediency, as it was difficult to get dirt enough to make that pack. The dirt taken down to make height in the roads made the packs in thinner seams. In the thicker seam the repairing dirt was sent in for packing. Probably if packs were made too wide they would not get the same results as those shown in Fig. 3 (Plate I.), where the angle of the dip was not only flattened over the pack, but it had altered the angle of the dip on the road as much as 10 degs. As regarded Mr. W. H. Wain's question as to robbing the packs or taking the back packings out, the distance of the pack had to be regulated by the nature of the roof. In the table given at the end of the paper it would be seen that the wastes varied from 8 to 11 yards, according to the nature of the roof. If it was found that the roof would not break at regular distances they were eased off—perhaps three wastes were eased into two. As regards the breaks these were exactly parallel to the line of the working-face and not square with the dip.

Mr. W. H. WAIN observed that that was the break-line, but the force would not be at right angles to it.

Mr. E. B. WAIN said that where the break was it showed the line of greatest force.

Mr. HAINES—The cleavage-lines?

Mr. E. B. WAIN said no; if they reversed the plan, they would find that exactly the same operation was performed on the other side of the pit. In this case, the face was crossing the cleat-line slightly, and on the other side it was almost at the end of the coal. The plan showed the north side workings, but the general lines on the other (south) side were the same, *i.e.*, there was a fall in the line of face from the out-bye to the in-hye end.

Mr. W. H. WAIN asked whether it was not found when there were breaks that the tendency was to force the packs out?

Mr. E. B. WAIN—No.

Mr. W. H. WAIN—If it was a slippery bottom ?

Mr. E. B. WAIN said he could show hundreds of yards in the gate-road in the Hardmine seam where the roads were packed 12 feet wide, and that width had not varied a foot since, and they had not cost a penny in datalling. With respect to the line of timbering, that was a point which had had a good deal of attention ; and the system of timbering was this—there must be three rows of posts at the working-face not more than $4\frac{1}{2}$ feet apart. Immediately the fall of coal was got out, the lowest row of posts was taken out and put in the middle. There they got three rows under 4 feet 6 inches, and with regular working it was almost unnecessary to have packs, as these three rows would be sufficient to keep the workings safe and good. There were, however, irregularities in working which would not allow that to be risked. The cost of timbering was less than it would be by working a half-hearted system.

Mr. HAINES enquired as to the cost ?

Mr. E. B. WAIN replied that it varied. It had been as low as $\frac{3}{4}$ d. in the thin seams and occasionally as high as $4\frac{3}{4}$ d. in the thick seams. That was for prop wood and main-road timber. The cost increased when the faces were not being pushed as they should be in slack time or holidays.

Mr. HIGGINS enquired how the ventilation was dealt with, the packs being small ?

Mr. E. B. WAIN said the ventilation was carried along the main road. The dips were stopped with two or three brattice-cloths, and in an extensive district there was a door at the bottom of several of the jigs on the out-bye end of a district. The air was carried right along the main road and down the slant at the end, and swept the working-faces. There was no probability of an accumulation of gas in the workings.

Mr. HIGGINS said there must be a large quantity of air lost, unless the roof was blown down and the packs buried.

Mr. E. B. WAIN—Certainly, we do this as far as practicable. It tended to interfere with the road, but as far as possible he tried to bury the dip-side pack, and as much of the head-side pack as circumstances would allow.

Mr. WM. BAILES asked what was the difference between working on the end and working on the face? Did they require more timber in working on the end than on the face?

Mr. E. B. WAIN said he had not noticed, and did not think, there was any difference, because the breaks in the roof seemed to be independent of any cleat-line.

Mr. BAILES thought that, if they were working to the dip, they would have to use another row of timber.

Mr. WAIN said that it had not been the custom to work these seams to the dip, but to the rise.

Mr. R. H. WYNNE said on the last occasion when this paper was discussed, mention was made about working different seams one above the other. Since the last meeting he (Mr. Wynne) had been reading a paper by Mr. Henry Wright in 1885, and he gave the plans of four seams close together, one slightly overlapping the other. Mr. Wright, speaking of the method of working coal at Whitfield colliery in 1885, said "with the seams of coal lying at short intervals from each other, when the workings in an upper seam are passing over the workings of a lower seam, a disturbance of the roof is brought on; this could not be otherwise, as only about 25 yards of strata lie between each seam, and the roadways have to be watched very carefully, as falls of roof will sometimes be brought on very suddenly. But where workings have been carried on underneath an upper seam, the roads in the upper seam have been so seriously disturbed as to require a very serious amount of labour and timber to reconstruct, and it does not appear at all advisable to work an upper seam first where it can be avoided."*

Mr. E. B. WAIN observed that, of course, expediency had a great deal to do with these matters. If they had a good coal and wanted to sell a great quantity it was natural to work it; but in practice, as far as possible, it was desirable to get the lower seam in advance. It reduced the labour of getting the seam above, and it was not so much affected by a seam working over it, as an upper seam would be by one working under it.

Mr. WYNNE said he had in his mind a case where the Hardmine and Holly Lane seams were being worked, and it was almost impossible to keep a road in the Hardmine seam. Very much timber was put in, and it was broken within twenty-four hours: and that was the strongest timber that could be put in. As to the thickness of packs, either above or below the main level, that was a matter of expediency to be applied to each particular case; but with other stratification the circumstances would be altered. The line of the breaks might be different.

Mr. E. B. WAIN explained, by reference to the plans (Figs. 2 and 5, Plates I. and II.), that the first breaks in two seams at different depths

* *Trans. North Staffs. Inst.*, vol. viii., page 65.

and with different nature of roof were almost in the same line. It was necessary to consider these breaks, as had been explained in the paper, because they showed the first line of pressure exerted on the packs after they were built.

Mr. BAILES, referring to the Spencroft and the Great Row seams, said it was better to take out the Great Row seam before the Spencroft.

Mr. WYNNE—Especially in such a system of longwall as that described by Mr. Wain.

Mr. J. BLAIKIE said he had always been at a loss to estimate Mr. Wain's "moderate inclination." He fancied it was a term which required defining.

Mr. E. B. WAIN said he should regard above 20 or 25 degs. as an extreme case.

Mr. BLAIKIE said he could not get exactly the angle of breakage from Figs. 6, 7, and 8, Plates I. and II. In Fig. 8 he understood it was 84 degs.

Mr. WAIN said it was 80 degs. from the horizontal, but from the dip of the mine it was 96 degs.

Mr. BLAIKIE asked if, in Figs. 6, 7, and 8, the inclination of the seams was the same?

Mr. WAIN replied that the inclination was not exactly the same: it varied 2 degs. in Figs. 7 and 8.

Mr. BLAIKIE—Then the angle is not taken under the same conditions?

Mr. WAIN—No; but the angle of main break is shown on the sections from the horizontal line in each case, and by adding the angle of the dip to it the angle made with the dip of the mine is easily found.

Mr. J. NEWTON proposed a vote of thanks to Mr. Wain for his able paper and the masterly way in which he had answered the questions which had been put to him.

Mr. H. R. MAKEPEACE, in seconding the resolution, said the paper was one which was calculated to give rise to a good deal of discussion, and it had done so. That day the discussion had been on the general method, whereas previously the discussion had branched off to a side stream. Mechanical engineers followed fixed rules; but mining engineers had to ascertain what course should be adopted under different circumstances, which varied greatly. It was seldom they found two mines working in exactly the same way. There were questions as to packing and timbering. A great deal depended as to how the packing was built. He had seen in many pits—he would not say whether in North Staffordshire or else-

where—where packs had been put in that had the appearance of having had the dirt tipped down without method. If the packing was thoroughly well put in, under conditions likely to stand pressure, very much less packing would do.

The resolution was carried unanimously.

Mr. LOCKETT read the following paper on “The Lockett and Gough Direct-acting Pump” :—

THE LOCKETT AND GOUGH DIRECT-ACTING PUMP.

 BY JAMES LOCKETT AND — GOUGH.

A great many of the direct-acting steam pumping-engines now in use do their work with a great amount of knocking at the end of the stroke. This knocking is caused by the piston-valve failing to reverse the slide valve at the proper instant, owing to a certain amount of steam blowing through the cylinder, caused by wear. This waste of steam reduces the pressure on the piston-valve and therefore causes delay in its action. The chief aim of the writers in their improvements in pumps and direct-acting steam cylinders has been to avoid this knocking and dead set, a purpose which they have accomplished by placing an independent small cylinder to work the main slide-valve. This small cylinder has a separate steam supply so as to allow of regulation, and to avoid any uncertainty in the action of the piston-valve.

The piston of the small cylinder (Fig. 3, Plate XV.) which operates the main slide-valve is a three-block piston. The centre block *g* is solid, the two end blocks *f*² and *f*³ (Figs. 3 and 4, Plate XIV.) are perforated, so as to offer little resistance to pressure on the centre or main block, and are used to determine the length of its stroke by covering the ports and cutting off the steam supply at each end of its stroke, thereby determining the stroke of the main slide-valve also. The slide of the small cylinder is worked by the action of tappet-rods, which pierce through each end of the main cylinder a suitable distance inside, and are operated by the piston as it nears each end of the cylinder. These tappet-rods being adjustable, the stroke of the main piston can be regulated, so as to avoid knock and waste of steam room at each end of the cylinder.

The pump in connexion with the steam cylinder differs from pumps in present use, by having its inlet or suction-valves coupled together. The suction-valves thus arranged are opened and closed by the discharge water, and there is no resistance to atmospheric weight, as the valves act instantaneously with the return stroke of the ram or bucket. This action makes the pump more certain in its action, and prevents expansion of air in the pump, as is the case with ram-pumps with a great amount of air-

space. A great advantage in connexion with valves thus arranged is, that should anything get on their face when they are closing, it would only affect the pump for one stroke, because by the return stroke of the ram or bucket the valve would lift again and free the obstacle. When anything gets on the face of the suction-valves of pumps in present use, nineteen times out of twenty the pump fails or becomes gagged and would lose its water.

The pump thus described offers no resistance to atmospheric weight, and it must fetch its water a greater distance than pumps in present use and possesses the advantage of discharging a constant flow.

Mr. C. H. TREGLOWN asked what advantage was claimed for this over the ordinary pump?

Mr. LOCKETT said it was easily adjustable—it could be adjusted while working.

Mr. TREGLOWN said it would be too expensive to make.

Mr. E. B. WAIN asked what was the difference between this and the Hathorne-Davey pump?

Mr. MAKEPEACE said it was similar.

Mr. TREGLOWN asked whether Mr. Lockett claimed to make improvements as regarded pause at the end of the stroke, when compared with the common direct-acting pump?

Mr. LOCKETT said there was no pause, no matter how slowly it travelled.

Mr. W. H. WAIN moved a vote of thanks to Messrs. Lockett and Gough for reading the paper before the Institute.

Mr. JOEL SETTLE seconded the proposition, and expressed a hope that Mr. Woodworth would examine the pump and bring his views upon it before a future meeting.

The resolution was then agreed to.

To illustrate Messrs Lockett and Gough's Paper on 'The Lockett & Gough Direct-acting Pump'

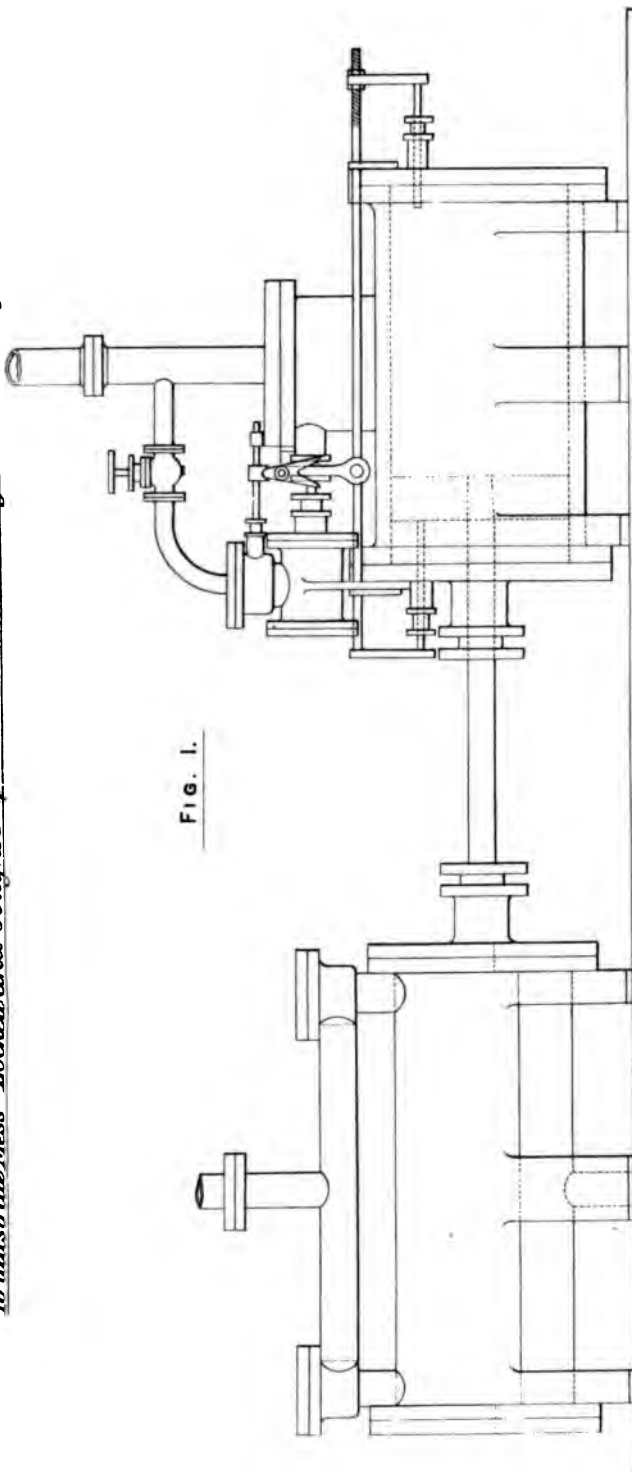


FIG. 1.

FIG. 2.

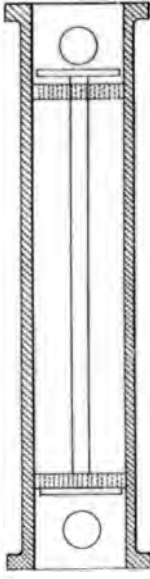


FIG. 3.

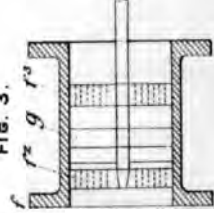
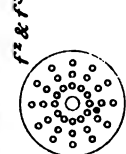


FIG. 4.





NORTH STAFFORDSHIRE INSTITUTE OF MINING AND
MECHANICAL ENGINEERS.

GENERAL MEETING,
HELD AT THE NORTH STAFFORD HOTEL, STOKE-UPON-TRENT,
MAY 8TH, 1893.

MR. ROBERT H. COLE, PRESIDENT, IN THE CHAIR.

The minutes of the last General Meeting were read and confirmed.

Mr. W. N. ATKINSON read the following paper on "The Use of Petroleum, Paraffin, and other Mineral Oils Underground":—

THE USE OF PETROLEUM, PARAFFIN, AND OTHER MINERAL OILS UNDERGROUND.

By W. N. ATKINSON.

It has been suggested that a discussion by this Institute upon the risks attending the use of petroleum, paraffin, and other mineral oils underground, would be useful and interesting. The writer has therefore had pleasure in making the following remarks to open the discussion, which he thought might be widened with advantage so as to include fires arising from other causes than mineral oils :—

Many members of the Institute will have received a circular, over the writer's signature, dated March 31st, 1893, on this subject. A similar circular was issued in all the inspection districts about the same time. The text of the circular was as follows :—

I am directed by the Secretary of State to call your serious attention to the risks attending the use of petroleum, paraffin, and other mineral oils underground without sufficient precautions being taken.

I am further to state that it seems very desirable that all the persons employed underground should be acquainted with the way of exit from the working-places by the "return airways," because circumstances arise—as, for instance, in some cases of fire—when it becomes dangerous to leave by the intakes, which, as a rule, are the only roads known to the majority of the workpeople.

The members will observe that the circular deals with two subjects : the risks attending the use of mineral oils underground, and the acquaintance of the workmen with a route of escape in case the roads ordinarily used become impassable, as they frequently do in case of fire.

The circular was issued in consequence of the fire at Bamfurlong colliery on December 14th, 1892, when sixteen lives were lost. That accident was caused by an ignition of mineral oil at an underground compressed-air hauling-engine. It appeared that, in order to prevent the formation of ice in the exhaust ports of the engine, paraffin oil was poured over the cylinder and ignited. That was obviously a dangerous practice, but the writer is uncertain whether the fire was caused in that way, or by the ignition of mineral oil while a torch lamp was being refilled, or by an explosion in a torch lamp containing mineral oil.

Other recent accidents, arising from fires underground, may be quoted :—

On September 5th, 1889, sixty-three lives were lost at Penicuik colliery, in the Midlothian coal-field. It could not be ascertained how this fire originated, but it was supposed that it might have been caused by one of the small torch lamps which the miners carry on their heads, setting fire to a brattice-cloth door.

On December 8th, 1881, a fire occurred on the engine-plane at Wheldale colliery in Yorkshire, and five lives were lost. It is probable that this fire was caused by a torch or comet lamp.

The last and most serious underground fire was that at the Great Western colliery in South Wales on April 11th, 1893, where sixty-three lives were lost. This fire appeared to have been caused by the heating of the brake of an underground compressed-air hauling-engine.

Of the four accidents cited, it appeared probable that three of them were caused by flaming-lamps. These lamps are both wasteful and dangerous, and especially dangerous when mineral oil is used in them, which renders them liable to explode.

Underground engine-houses are particularly liable to fires. They are usually dry and warm and often contain much timber, and the oil required by the machinery is a source of danger. Bricks and iron might be used in many cases to replace much of the timber. Oily cotton-waste should be sent out of the pit. A few hand-grenades for extinguishing fires might be kept within reach of the engineman. Lamp-rooms should not be located underground. Mineral oil should not be stored in mines, even in small quantities, but all lamps should be sent to the surface to be refilled. The use of petroleum engines should not be resorted to in dry coal-mines. Furnaces and boiler-fires underground should be avoided as much as possible.

With regard to the means of escape in case the roads ordinarily used are not available, notice-boards might be put up to show the way, and some of the workmen from each district might be taken out by the return airway at intervals. It was also important that the escape route should be kept free from impediments and made as easy to travel as practicable, dangerous places being fenced off and staples or blind pits fenced and provided with good ladders, and no serious accumulations of water allowed on the road. At the escape-shaft, proper landing-places and means of signalling should be provided, and it would be advantageous in cases where the apparatus for raising and lowering persons was not in actual use, that it should be used at regular intervals to see that all was ready in case of emergency.

Mr. E. B. WAIN said that the Inspector's circular called attention to "the risks attending the use of mineral oils without sufficient precautions being taken," but in his opinion there was danger in the use of mineral oils even when every possible precaution was taken, particularly in dry-timbered roads, or where there was any quantity of timber about. He had recently been obliged to face this difficulty in one of the pits of which he had charge, where, although the pit bottom was arched with brickwork, there was about 3,000 square feet of timber-staging. In this case, paraffin lamps of good make had been used, and every care taken in trimming and cleaning the lamps, one of the lamp-men going down twice a day to attend to them, and taking only what oil was required with him. Even with these precautions, lamps had been thrown down, and there had been several narrow escapes from fire. In order to entirely overcome this risk, a small electric-lighting plant had been fixed, and had been working since the commencement of the year. To light the top and bottom decks, twenty-five 16-candle-power lamps were used, which were supplied with current from a small dynamo giving an output of 15 ampères at 100 volts. This was driven by an engine with one cylinder 5 inches in diameter and 7 inches stroke, running at 200 revolutions per minute. The speed of the dynamo was 640 revolutions and the whole space occupied by the engine and dynamo was 8 feet by 3 feet by 5 feet high. The same care had been used in fixing the wires, etc., as would be taken in house and ship lighting, where the work would have to pass insurance companies and Board of Trade inspectors. The leads used were highly insulated, lead-covered, and enclosed in strong wooden casing. The joints were all made in cast-iron airtight junction-boxes, and the lamps were enclosed in globe fittings, also airtight, and surrounded by a strong wire guard to save breakage by accidental blows. The whole cost of the work was under £200, including a spare armature for the dynamo. It would be quite possible to put in a plant to do the same work at about half the cost, if bare wires were carried on insulators and the joints spliced, but there would be some danger of intense heat in such a case if the wires should accidentally come together and short-circuit the current; but by using the high insulation and junction-boxes, which also contained safety-fuses, this danger was entirely overcome. The engine was supplied with steam from the main-pipe taken down the pit to supply the underground hauling-engines, and the working cost was practically nothing, as the engineman was able to attend to the lubrication, etc., at intervals of three or four hours. The lamps formerly used burned some nine or ten gallons of paraffin per week, and did not light the pit bottom nearly so well as the electric lamps. The cost in renewals of lamp glasses

would be rather more than the renewals of electric lamps. It would be seen that with the electric plant there was greater safety, more efficient lighting and economy in working, although it was admitted that small dynamos were not so economical in their working as larger machines. By far the most dangerous form in which mineral oils were used underground was when burned in flaming or torch lamps, and it seemed desirable that these should be forbidden altogether, except, perhaps, for the purpose of shaft examinations. He had in several cases substituted colza-oil lanterns with a $1\frac{1}{4}$ inches wick for torch lamps, and the men who had to use them found them better to work with and quite as convenient. Where the use of paraffin could not be avoided without inconvenience it was highly important that a stand-pipe, with good pressure of water and hose-pipe attached, should be fixed and available for immediate use. As regarded the travelling of return airways by the workmen, there should be very little difficulty in making them familiar with the roads if proper guide-boards were fixed at the various junctions leading into the return, and all roads not used for haulage purposes should be carefully fenced off from the travelling road. It seemed also desirable (where possible) that there should be a road to the downcast pit on a higher level than the pit-bottom, so that in case of fire in the pit-bottom it would be possible for men to get to the fresh air of the downcast. Where the only outlet was by the upcast, in pits of small area, with a high velocity of the air-current, it was quite possible that the air at the bottom of the upcast pit would soon be rendered unsafe to breathe. And last of all, it seemed to be absolutely necessary that all special outlets into the shaft should be fitted up with proper signalling appliances. In the case of the recent fire at the Great Western colliery, there seemed to have been a great number of lives lost through one of the insets not being fitted with signals, and some delay in drawing out the men taking place. In conclusion, he felt that they ought to strengthen the hands of the inspectors by doing all in their power to carry out the suggestions in the circular.

Mr. W. H. WAIN explained that, in the case in which he had put a Priestman oil-engine underground, the greatest care was used in the construction of the engine-house, no timber being used in the same. He believed the special instructions supplied for working the engine were approved by the inspector at the time.

The PRESIDENT said Mr. E. B. Wain advocated prohibition of the use of oil except in the lamp.

Mr. E. B. WAIN said he did not wish to convey the impression that he would prohibit the use of paraffin for lighting purposes altogether, but he certainly would forbid the use of torch lamps underground.

Mr. J. RICHARD HAINES said he thought the time had nearly come when no naked light should be allowed in a coal-mine. He made it a rule that every lamp was sent to the surface to be relighted. It was not perhaps the most convenient system to adopt, but he was inclined to consider it the safest plan and to believe that benefit would arise from its enforcement. As to the precautions which had been suggested to deal with underground fires, prevention was better than cure, and hot firebricks or bricks made of cast-iron and heated would prevent freezing if simply laid on the cylinders and valve-chests of compressed-air engines; he had used them successfully for a considerable time. Means should also be at hand to deal with fires on the surface: a very good fire-engine was always at hand in the donkey-pump, all that was needed being a connexion and a few lengths of hose, which should be occasionally attached and used. These simple precautions would in many cases prove useful and prevent the extension of the fire, even if not sufficient to suppress it, provided the enginemen, firemen, and others were instructed in the use of the apparatus.

Mr. J. STRICK said he had always held that he would never, if possible, allow any fire down a pit except that in the miner's safety-lamp, or the lights at the pit bottom. He recollected two accidents which occurred from the use of paraffin or light oils. The first was during the night shift. The butties had taken a cask of torch-oil down the pit. A man was filling a lamp which exploded and set fire to the pit-bottom. The bottom was dry and the fire had to be drowned out. A close scaffold was tried; but those who thought they could extinguish such a fire by a close scaffold were mistaken. This colliery was re-opened at great expense, and while the engineman was refilling a paraffin lamp, he set fire to the engine-house and burnt out the pit-bottom again. After that experience he never used paraffin in a colliery again.

Mr. JOHN LEE observed that they should try to instil into the minds of the engineman to keep the engine clean, both from swarf, oil, and waste. They ought to send out dirty waste every week, or every day, and not allow it to accumulate.

Mr. MITCHESON asked if any one knew of a case similar to that at the Great Western colliery, where a brake had caused a fire, or whether any one knew of a fire having been caused by the overheating of haulage pulleys underground?

Mr. E. B. WAIN said he had in his mind a case of overheating of the brakes on the surface, but he did not know why it should not occur.

Mr. MITCHESON suggested that was an argument in favour of having

all engines on the surface. He had known one fire on the surface caused by overheating of the brake.

The PRESIDENT asked if any gentleman would address himself to the question of the travelling-roads?

Mr. MITCHESON said if they put up notice-boards and fenced off roads as had been suggested it was comparatively simple; and it would not be a difficult matter to select a couple of workmen out of each district weekly and send them through the return with the fireman.

Mr. W. N. ATKINSON thought that would be a reasonable solution of the question. There was no doubt that the actual travelling on the road by one or two men would be of far greater benefit than any notice-boards, because even with notice-boards there would be difficulty, especially where there were three roads leading in different directions. But there should not be any difficulty in taking one or two men from each district at intervals by the alternate road to which they were not accustomed. That practice would also be beneficial in other ways. It would lead to these routes not regularly used being kept in a better state than they were sometimes. They were sometimes not so easy to travel as they might be, both as regarded the size and the difficulties in getting up steep places. If these things were brought under the notice of the men in a colliery, no doubt more attention would be paid to them than was sometimes paid under existing circumstances.

Mr. STRICK proposed a vote of thanks to Mr. Atkinson for having brought these questions under their notice, the discussion of which could not be otherwise than useful.

Mr. W. HEATH seconded the proposition, observing that he quite agreed with all that had been said. There was only one difficulty, that they would not get the workmen to go round without payment.

The resolution was agreed to, and briefly acknowledged by Mr. Atkinson.

DISCUSSION ON MESSRS. LOCKETT AND GOUGH'S PAPER ON "THE LOCKETT AND GOUGH DIRECT-ACTING PUMP."*

Mr. BENJAMIN WOODWORTH said that the most important requirement in a direct-acting pump in his opinion, was a controlling-apparatus or governor that would safely deal with false strokes in working; but this

* *Trans. Fed. Inst.*, vol. v., page 481.

pump, like the generality of such pumps, did not attempt anything of that kind. The tappet arrangement was not absolutely novel, although the connexion between it and the main valves might be a new combination; and, if applied to a large pump, the question was whether a false stroke might not lead to serious damage, as there must be a measureable element of time consumed in the movement of the main valve-gear through the auxiliary cylinder, and injury might arise in that interval in the case of false-stroke working. As regards the claim to avoid the set at the end of the stroke, he thought it was a mistake to do so, as the pause or set in such pumps was very desirable for good working and the durability of the valves, etc. He thought an attempt should be made to secure (instead of to avoid) such action in any important pumping-plant of the direct-acting class, and perfect action of this kind for heavy lifts made the use of such pumps preferable to the ordinary rotatory pumping engine. In all large or moderate-sized pumps he should object to the piston-rod proper entering the pump, although the pump was thereby rendered shorter and more compact by so doing. The triple-block piston in the auxiliary cylinder was a very ingenious and decidedly novel arrangement, and the steam-port when open (he presumed) was between the central solid piston and the outer perforated piston, and if so, piston f^1 and not f^2 (Fig. 3, Plate XV.) should be described as the one that covered the port, but this no doubt was a clerical error that had crept into the specification. The suction-valve arrangement with two valves fast on one central spindle was probably new, but it did not necessarily follow that it was an improvement, as the trouble with such valves was generally not from any difficulty of their opening but from heavy blows on closing, if they were not properly designed or proportioned. This arrangement would in his opinion slightly increase that risk, especially if the quick return was used (that was claimed as an advantage in this pump), and of course this trouble should be avoided as far as practicable in both suction and delivery-valves. The proportion for suction-valves and casing would be found very unsatisfactory in working, as the casing area internally was only one-ninth of the pump, and the passages through the valve-seating and round the annular space between valve and casing could not possibly reach 5 per cent. of the area of the pump, a proportion much too small for ordinary working—but that was simply a detail which anyone making or using the pump would easily avoid.

Mr. J. NEWTON said it was rather unfortunate that neither the model nor the inventors were present. He thought when the paper was read that the writer ought to have given them comparative results, showing what other pumps could do and what it was claimed that this pump would do.

But it appeared from the turn the discussion took at the last meeting that they were not likely to have any very extensive comparisons made. The only point upon which argument might be raised, so far as he could see, was the set of the valve. With regard to Mr. Woodworth's remarks, he would venture to say that although it was accepted that the set of the valve at the end of the stroke was an advantage, it was at the same time a great disadvantage. And he would tell them why: the return of the piston against a solid body was a disadvantage to the mechanism. They also knew that if they had 300 yards of head of water they had a great amount of friction in the pipe through which they were forcing the water. To overcome the friction after the water had settled into a dormant position would entail greater energy than it would to keep the water in motion when once it had been started, and would be more injurious to the machinery than the absolute knock against the solid fluid on the return of the piston. As the piston returned against the fluid, if there was no set there would be very little knock on the valve, or concussion of machinery, and it would be a less disadvantage than the lifting of the water after it had ceased to flow.

Mr. C. H. TREGLOWN said he had much pleasure in endorsing the acknowledgment of the last meeting that the members were indebted to the author for having brought before them an improved pump. When looking at the model exhibited at the last meeting he had an impression that the author claimed the production of a pause at the end of the stroke, but to his surprise he distinctly understood the author to say he did not. Since then he had observed in the specification one of the principal claims was worded thus:—"and avoiding the dead set or stopping at each end of the stroke." Whatever that might mean was not clear to him. The specification seemed to embrace some points of other well-known direct-acting pumps, but until the pump was made and worked under fairly average conditions, it would be premature to pass any conclusive opinion on it. He (Mr. Treglown) quite agreed with the words of a previous speaker as to the loss of time between the piston striking the tappet-rods and the reversal of the main slide-valve, and this perhaps would be more apparent when it was remembered in cases of losing water, or load, or in instances to meet sudden demands, the piston travelled at great speed, and the motion had to be transmitted through rods, levers, rocking-shaft, pins, and joints, with the necessary freedom which many parts must have, and the question was, even were there provision for cushioning (and there seemed none), whether this lapse of time would not cause the piston to strike the cylinder end, necessitating the lateral rod adjustment the author spoke of. But it

must not be forgotten that any adjustment which shortened the travel of the piston was detrimental rather than otherwise to the efficiency of the machine ; and was it possible to maintain constantly the full length of the stroke, because, to provide for high speeds above referred to (and with which the best direct-acting pumps of the day had no difficulty) the tappet-rods must project proportionately far into the cylinder, and when working slow or under normal conditions it would appear the piston would not travel the full length of the stroke. It would appear also that wear and tear would be considerable ; even at a slow speed, the tappet-rods would receive many hundreds of blows per hour, and these tappet-rods had to work against the friction of three stuffing boxes and of the slide-valve of the auxiliary cylinder, and further there was the constant working of the pins, joints, and lever-ends on the lateral-rod and rocking-shaft, and the wear that would undoubtedly take place must be compensated by adjustment of the lateral-rod. Most direct-acting pumps combined the advantages of the vertical arrangement. Was it intended to work the pump vertically ? If so the provision for balancing did not seem very clear. With regard to the suction valve arrangement, practical work could only demonstrate the value, but he (Mr. Treglown) could see no advantages over the most approved arrangements of modern direct-acting pumps. All inventors were deserving of much credit and encouragement, but when he looked at the increased cost of production and other features he did not approve of, he was inclined to think it was possible their expectations might not lead up to all they might have anticipated. He (Mr. Treglown) considered a pause at the end of the stroke was a decided advantage, as it gave time for the closing of the pump-valves.

Mr. B. WOODWORTH said he thought Mr. Newton was under a mistake in stating that they could start the water from the reverse end of the pump without causing reaction, he thought the quicker it started the greater would be the reaction.

CHESTERFIELD AND MIDLAND COUNTIES INSTITUTION
OF ENGINEERS.

ANNUAL GENERAL MEETING,
HELD IN THE STEPHENSON MEMORIAL HALL, CHESTERFIELD.
JULY 1ST, 1893.

MR. HENRY LEWIS, RETIRING PRESIDENT, IN THE CHAIR.

Mr. Ford and Mr. Hirst kindly consented to act as scrutineers of the voting papers for the election of Council for the ensuing year.

The SECRETARY announced the election of the following gentlemen :—

MEMBER—

Mr. WILLIAM HAY, Stanton Colliery, Burton-on-Trent.

ASSOCIATES—

Mr. JOSEPH BRADFORD, Deputy, Netherseal Colliery, Burton-on-Trent.

Mr. WILLIAM FREDERICK COLLINS, Borer, Netherseal Colliery, Burton-on-Trent.

Mr. JOHN DOWNING, Enginewright, Charity Colliery, Bedworth.

Mr. WILLIAM JOHN GRAY, Under Manager, Birley Collieries, Sheffield.

Mr. REGINALD HIGGINBOTTOM, Mining Surveyor, Glapwell Colliery, Chesterfield.

Mr. RICHARD WILLIAM LAMBERT, Under Manager, Birley Collieries, Sheffield.

STUDENT—

Mr. WILLIAM DEAKIN WADSWORTH, Jun., Mining Surveyor, Newbold Road, Chesterfield.

REPORT OF THE COUNCIL.

The following is the usual comparative summary of the number of members and the state of the finances in the past three years, viz. :—

	1890-91.			1891-92.			1892-93.			
Honorary Members	...	15	...	15	...	14	...	14		
Life Members	...	8	...	6	...	7	...	7		
Members	...	191	...	193	...	204	...	204		
Subscribing Members	...	7	...	9	...	7	...	7		
Associate Members	...	19	...	22	...	31	...	31		
Students	...	11	...	16	...	19	...	19		
		<u>251</u>		<u>261</u>		<u>282</u>				
		<u>£</u>	<u>s.</u>	<u>d.</u>		<u>£</u>	<u>s.</u>	<u>d.</u>		
Cash Receipts	...	379	4	6	372	5	4	444	13	11
Cash Payments	...	396	11	1	396	3	5	501	13	9
		<u>29</u>	<u>2</u>	<u>3</u>	<u>5</u>	<u>4</u>	<u>2</u>	<u>-51</u>	<u>15</u>	<u>8</u>
Bank Balance	...	533	6	8	533	6	8	533	6	8
Invested Fund	...	<u>£562</u>	<u>8</u>	<u>11</u>	<u>£538</u>	<u>10</u>	<u>10</u>	<u>£481</u>	<u>11</u>	<u>0</u>
Arrears considered recover-										
able at end of	...	1890-91.		1891-92.		1892-93.				
		£52	8	0	£45	10	6	£39	16	0

One Life Member, 19 Members, 11 Associate Members, and Students have been elected during the year—a total of 36 (as against 2 last year).

The total retirements from all causes are 15 (as against 15 last year viz. :—1 Honorary Member, 12 Members, and 2 Subscribing Members.

There has been a net increase of 1 Life Member, 11 Members (including 2 Associate Members and 2 Students who have become Members), 9 Associate Members, and 3 Students; and a net decrease of 1 Honorary Member and 2 Subscribing Members.

One Honorary Member and 3 Members have died during the past year, and are further referred to in Memoirs (see page 480).

The total number on the roll of the Institution as for the year commenced 26th March, 1893, was 282.

The income of the past year was £72 8s. 7d. more, and the expenditure £105 10s. 4d. more than the same in the previous year.

The expenditure has been £56 19s. 10d. in excess of the year's income.

The only extraordinary receipt during the year was £21 for a new Life Member. Two present Members offered and still offer to commute their annual subscription in like manner, but the Council have hitherto declined to accept, doubting that advantage beyond temporary financial aid would be the result of life memberships, particularly should the rates of Members' Subscriptions be raised to cover experimental or any purposes beyond the present undertaking of the Institution and involving increased outlay from the funds. Such an undertaking—reprinting the French Commission Report on Explosives and Fire-damp—has, in fact, swelled the year's expenditure by £40 12s. 1d. As the last year's Report stated, the Council had then directed this item to be paid for out of the reserve fund. A further outlay of £38 8s. resulted from a special call beyond the agreed 15s. per member to cover the first three years' deficiency of the Federated Institution. The two items, amounting to £79 0s. 1d., more than account for the excess of expenditure over income, after deducting the exceptional £21.

The Council are unwilling to touch the Debenture Stock reserve, and still more so to propose increased rates of subscription. There seems reasonable ground for expecting that, with the greater membership of the Federated Institution of Mining Engineers, the cost per head for publishing the *Transactions* will be kept down, whilst the large addition to our own local membership shown in the preceding numerical statement for the past year, and since very materially augmented, encourages the probability of the next year's results being somewhat more favourable.

The arrear list is lower than it has been for many years, whilst the amount struck out as irrecoverable is less than in the previous year; the *Transactions* are withheld from all whose last year's subscription is unpaid.

A General Meeting of the Federated Institution of Mining Engineers, for the second time held in the district of this Institution, on February 22nd and 23rd, 1893, at Derby, and the neighbourhood, was numerous and throughout satisfactory. At the Annual General Meeting held previously in September, 1892, at Stoke-upon-Trent, Mr. George

Lewis, senior Past-President of this Institution, was unanimously elected President for the year. The other General Meeting was in London on June 1st, 2nd, and 3rd, ult.

Local meetings have been held in Nottingham on June 25th and December 3rd, 1892, and in Sheffield on April 8th last. A Joint Meeting with the Midland Institute was also held at Sheffield on April 8th.

The complete list of papers communicated since the Council's last Report is as follows :—

- "Underground Haulage by Endless-rope at Ansley Hall Colliery." By W. G. Phillips.
- "Witwatersrand Gold-field, Transvaal, South Africa." By J. P. Hamilton.
- "Notes on the Natal Coal-fields." By J. P. Hamilton.
- "Presidential Address." By Henry Lewis.
- "One Use for the Telephone." By F. S. Marsh.
- "Memoir of Lord Edward Cavendish."
- "Memoir of the Seventh Duke of Devonshire."
- "Memoir of George Howe."
- "Memoir of Edward Soar."
- "An Improved Head-gear for Pit Horses." By G. J. Binns.
- "Geological History of the Rawdon and the Boothorpe Faults in the Leicestershire Coal-field." By W. S. Gresley.

This Institution by its increased membership has become entitled to have an additional representative on the Council of the Federated Institution, and by the terms of notice given last meeting in this respect, Mr. Alfred Barnes will join the present representatives. The Council heartily congratulate the Institution on the admission of so many new members of various classes. Their hope that the Institution would be thus speedily and materially strengthened has been realized, but there are still many more who ought to be enrolled, and among these are the whole of the lessors of mines throughout the Midland Inspection District.

The resolution, of which due notice has been given, and which is precisely expressed in the agenda for this Annual Meeting, to amend the classification of members in conformity with a model bye-law of the Federated Institution will, it is believed, have the effect of giving increased value to full membership whilst preserving the privileges of all classes. The new class of Associate Members obtains special privilege in the power to vote with members upon all questions. The Council trust that this resolution, which has been well considered, will be adopted and incorporated in the rules.

The thanks of the Institution are due to the President (Mr. Henry Lewis), who not only during his term of office but on previous occasions

has done substantial service to the Institution. His successor, Mr. Alfred Barnes, the President-elect, will deliver an address, and has moreover as head of the Grassmoor Colliery Company provided for the reception and instruction of the meeting by throwing open the group of collieries at Grassmoor to be visited.

The next meeting of the Federated Institution of Mining Engineers is fixed to take place in Glasgow and the district of the Mining Institute of Scotland which has recently joined the Federation.

ABSTRACT OF ACCOUNTS,

INCOME.						£	s.	d.	£	s.	d.
168	Members	...	...	...	...	264	12	0			
	One classed Student paid increase as Member	...	...	...	...	1	2	0			
8	Subscribing Members	...	...	...	...	8	8	0			
31	Associates and Students	...	...	...	...	31	0	0			
1	Paid and became Member as above	...	...	...	...	1	0	0			
1	New Life Member...	...	...	...	...	21	0	0			
10	New Members and Entrances	...	...	...	...	26	5	0			
1	Do. re-entered, subscription only	...	...	...	...	1	11	6			
9	New Associates and Students	...	...	...	...	9	0	0			
									363	18	6
229											
	Four Members paid in advance	...	...	...	...	6	6	0			
	One paid old arrear not in list	...	...	...	...	3	3	0			
	One late Student paid in advance and Entrance	...	...	...	...	2	2	0			
	Seven New Members Do.	...	...	...	...	18	7	6			
	Do. Associates Do.	...	...	...	...	7	0	0			
									36	18	6
									400	17	0
	Arrear Subscriptions received for 1890-91	...	...	...	...	4	3	0			
	Do. do. 1891-92	...	...	...	...	13	0	6			
									17	3	6
									418	0	6
	Transactions and Excerpts sold	...	...	...	...				3	15	0
	Midland Railway Company's Debenture Interest	...	...	...	...				15	12	0
	Bank Interest	...	...	...	...				2	2	9
	Letting of Council Room	...	...	...	...				1	0	0
	Midland Institute Share of Joint Meeting, May 3rd, 1892	...	...	...	...				3	7	9
	Chesterfield Corporation Classes—Gas repaid...	...	...	...	...				0	15	11
	Total Receipts	...	...	...	...				444	13	11
	Unpaid Arrears, per Subscription a/c	...	...	...	...	34	11	0			
	Do. 1890-91 Account	...	...	...	...	17	6	6			
	Do. Previous years	...	...	...	...	11	0	6			
									28	7	0
									62	18	0
	Irrecoverable	...	...	...	...	23	2	0			
	Net arrears to collect	...	...	...	...				39	16	0
	Balance from last year	...	...	...	...	5	4	2			
	Do. as per contra	...	...	...	...	51	15	8			
									56	19	10
									£541	9	9

Certificate of £533 6s. 8d. Midland Railway Company's 3 per Cent. Debenture
Stock, and Policy of Insurance Alliance Co., deposited in Bank.

YEAR ENDING MARCH 25TH, 1893.

EXPENDITURE.				£	s.	d.	£	s.	d.
Federated Institution of Mining Engineers for copies of									
Transactions, supplied at 15s. per Member:—									
Balance on Call, 1891-92 (Vol. III.) ...	...	...	...	106	10	0			
Proportion of Special Call to meet first three years' deficiency ...	...	...	...	38	8	0			
Instalments on Call, 1892-93 (Vols. IV. and V.) ...	...	...	...	105	7	6			
							250	5	6
Excerpts, Back Volumes, and Reprints ...	...	...	...				19	0	3
French Commission Report—Explosives and Fire-damp ...	...	...	...				40	12	1
Reid, A., Sons & Co., Printing and Stationery ...	...	...	...	12	13	7			
Bemrose & Sons, Ltd. do. do. ...	...	...	...	13	10	2			
Sundry Printing and Stationery ...	...	...	...	2	17	8			
							29	1	5
Auditors ...	...	...	...				3	3	0
Reporting Proceedings ...	...	...	...				11	14	8
Stephenson Memorial Hall (Occupation) ...	...	...	...				15	12	7
Fire Insurance ...	...	...	...				0	12	6
Postages, Parcels, and Telegrams ...	...	...	...				15	18	9
Travelling and Incidental Expenses ...	...	...	...				15	1	6
Requisites and Services ...	...	...	...				2	13	11
Joint Meeting with Midland Institute, May 3rd, 1892, part cost ...	...	...	...				5	3	9
Federated Institution Meeting, Derby, February, 1893 ...	...	...	...				6	18	3
Secretary's Salary, Assistance, and Use of Office ...	...	...	...				85	0	0
Bankers' Charges ...	...	...	...				0	15	7
							501	13	9
Total Expenditure ...	...	...	...						
Net in Bank in respect of Forward Year ...	...	...	...	227	18	6			
Balance in Messrs. Crompton & Evans' Union									
Bank, Ltd., Chesterfield, June 17th, 1893	186	7	9						
Less, Outstanding Cheques ...	10	4	11						
				176	2	10			
							51	15	8
Arrear Subscriptions ...	...	...	...				39	16	0
							£541	9	9

June 19th, 1893,

Examined and found correct,

JOHN HALL,
JOHNSON PEARSON, } AUDITORS.

DR.

THE TREASURER IN ACCOUNT

	£	s.	d.	£	s.	d.
193 Members, as per List, 1892-3	303	19	6			
Less five paid in advance last year	7	17	6	296	2	0
One classed Student paid increase as Member ...				1	2	0
Four Members paid in advance, 1893-4	6	6	0			
Seven New Members do. and Entrances	18	7	6			
One late Student do. do.	2	2	0			
One paid arrear not in list	3	3	0	29	18	6
9 Subscribing Members				9	9	0
38 Associate Members and Students	38	0	0			
Four paid last year in advance	4	0	0	34	0	0
1 New Life Member				21	0	0
10 New Members and Entrances				26	5	0
1 New Member re-entered, subscription only				1	11	6
11						
9 New Associates and Students				9	0	0
Seven New Associates paid in advance				7	0	0
261				435	8	0
Arrears per last Balance Sheet	45	10	6			
Deduct Irrecoverable Arrears not included in 1893-94						
List	23	2	0	22	8	6

£457 16 6

ACCOUNTS.

451

WITH SUBSCRIPTIONS, 1892-3.

Cr.

								Unpaid.	Paid.
								£ s. d.	£ s. d.
168	Members	...	...	...	...	...	...		264 12 0
5	Paid last year in advance	...	...	...	...	...	...		
20	Unpaid	...	...	...	...	...	...	31 10 0	
193									
	One classed Student paid increase as Member	...	...	...	...	...	...		1 2 0
	Four Members paid in advance, 1893-4	...	...	...	...	...	...		6 6 0
	Seven New Members do. and Entrances	...	...	...	...	...	...		18 7 6
	One late Student do. do.	...	...	...	...	...	...		2 2 0
	One paid old arrear not in list	...	...	...	...	...	...		3 3 0
8	Subscribing Members	...	...	...	...	...	...		8 8 0
1	Retired	...	...	...	...	...	...	1 1 0	
9									
31	Associate Members and Students	...	...	...	...	...	...		31 0 0
4	Paid last year in advance	...	...	...	...	...	...		
1	Paid and became Member as above	...	...	...	...	...	...		1 0 0
2	Unpaid	...	...	...	...	...	...	2 0 0	
38									
1	New life Member	...	...	...	...	...	...		21 0 0
10	New Members and Entrances	...	...	...	...	...	...		26 5 0
1	New Member re-entered, subscription only	...	...	...	...	...	...		1 11 6
11									
9	New Associates and Students	...	...	...	...	...	...		9 0 0
	Seven New Associates paid in advance	...	...	...	...	...	...		7 0 0
261								34 11 0	400 17 0
	Arrears as per last Balance Sheet	...	...	...	...	...	...	28 7 0	17 3 6
								62 18 0	418 0 6
	Irrecoverable	...	...	...	...	...	...	23 2 0	
	Arrears to collect	...	...	...	...	...	...		39 16 0
									£457 16 6

June 19th, 1893.—Examined and found correct,

JOHN HALL,
JOHNSON PEARSON, } AUDITORS.

Mr. G. J. BINNS (Netherseal) thought that the status of the Institution would be maintained and its prosperity extended if they had a greater number of Associates. This had not been a class which had been much cultivated in the past, but it was one to which he thought they might pay attention with very great advantage. There was at every colliery only one manager, but at the large collieries there were numbers of men, under managers, enginewrights, deputies, etc., who were competent to join them, and would be glad to do so if they knew that they were eligible to become Associates, and to obtain such advantages as were contained in the valuable volumes of *Transactions*. He hoped the members of the Institution would endeavour to get all such men they could to join as Associates.

Mr. GEORGE LEWIS (Derby) had no wish to criticize the report of the Council, as to which he thought they all could congratulate themselves on having such a good report for the past year. He thought it was very satisfactory to know that in two years their members had increased from 251 to 282. He had been connected with the active management of the Institution for some years, and only those who were on the Council knew the difficulties that attended them in dealing with an institute of that character. Some few years ago they were very much afraid that the Institution would cease to exist as an institute, for the members were gradually decreasing, and the Council were much exercised as to what was the best course to take. It would be within the recollection of some members that overtures were made to the Midland Institute with the view of federating so far as the two institutes were concerned, and by that means increase the members and so reduce the working cost per head. Negotiations proceeded for some little time, and then for a variety of reasons fell through; but eventually they became federated with the general body of mining institutes throughout the country. He thought federation had been very satisfactory up to the present moment, and to point more particularly to what he meant, that morning he had received a letter from the Secretary of the Federated Institution of Mining Engineers (Mr. M. Walton Brown) stating that the *Transactions* for this year were so bulky that in all probability it would be necessary to issue two volumes instead of one. That proved what great interest was being taken in the Institution generally, and that valuable papers were being written, and that they not only were published for the benefit of a few members of one local institute but were sent all over the world. The expenses had been very little more as regards their own Institution, but they certainly required more members to make it work efficiently. The expenses of publication, maps, and printing

generally were very heavy, and then (what might seem a small matter) the cost of postage amounted to a very large proportion of the working cost. It seemed to him (Mr. G. Lewis) that in a district like theirs, embracing the counties of Derbyshire, Nottinghamshire, Warwickshire, and Leicestershire, considerably more than 282 persons were practically engaged in the supervision of mines. There must be considerably more, and he thought it eminently desirable that, as Mr. Binns intimated, each one who had practical supervision should become a member of that Institution, and he hoped that the result would be that by this time next year their numbers would be considerably increased. They were not well off as regards funds, but they hoped their financial position in the near future would be somewhat improved.

Mr. M. DEACON (Blackwell) said Mr. Lewis had referred to the large number of papers they were receiving from the Federated Institution of Mining Engineers, and now that they had reduced the number of their meetings to three a year in consequence of the formation of the Federated Institution of Mining Engineers, this seemed to him to operate very much against a proper discussion of the papers. He did not know whether he was in order in raising that question then, but he felt, if the papers were to have full value, they ought to have better opportunities of discussion than they now had by only meeting three times per annum.

The CHAIRMAN said there was not the slightest doubt that the accounts showed a small loss during the year, and the only way of altering that was by increasing the subscriptions or the number of members. The former method would not find favour, but he thought and hoped after what had been said and considering the very useful *Transactions* they were now getting from the Federated Institution of Mining Engineers, that large numbers of new members would be attracted. The papers themselves were worth far more money than the amount of the subscription, and he hoped at the end of twelve months that their present numbers would have increased from 288 to 388, and that their financial difficulties would be at an end. He then moved the adoption of the report, etc.

Mr. A. G. BARNES (Grassmoor) said the exceptional expenditure in printing the Report of the French Fire-damp Commission ought not to be charged to the present year, but should come out of the accumulated funds.

Mr. J. A. LONGDEN (Stanton) said he knew that the Council had passed a resolution to charge the cost of the publication of the French Commissioners' Report to the reserve fund. He was surprised when reading the Report of the Council to see that the original proposition had

been altered. He certainly thought this was the better way of dealing with the matter, namely, that the item of £40 12s. 1d. should be taken out of the current year's expenditure, as suggested; and if Mr. Barnes would make a proposition to that effect, he would second it.

Mr. A. G. BARNES said he had pleasure in doing so.

Mr. LONGDEN then seconded the proposition.

Mr. J. BAGNOLD SMITH (Newstead) said that, as he felt bound to oppose the resolution, he would give his reasons for taking that course. The cost of the French report was not a regular item of expenditure which would recur year by year, it was an exceptional item. He therefore was of opinion that the expense should be spread over a term of say three years, and not wholly debited to the past year. He thought it would not be desirable to sell out any of the invested funds of the Institution.

Mr. A. G. BARNES, upon a suggestion of the Chairman to withdraw his proposition, called for a division on the matter.

Mr. LONGDEN did not wish to be personal, but Mr. Elmsley Coke and he had agreed to become Life Members so as to avoid the necessity for selling a part of the invested stock.

The CHAIRMAN having put the resolution, upon which 5 voted for it and 4 against, most of the members present not voting, said it showed how much interest the members had taken in the discussion.

The Report was then adopted unanimously.

ELECTION OF OFFICERS, 1893-94.

PRESIDENT.

ALFRED BARNES, Esq., Ashgate Lodge, Chesterfield.

VICE-PRESIDENTS.

M. DEACON, Esq., Blackwell Collieries, Alfreton.
 W. D. HOLFORD, Esq., Whittington, Chesterfield.
 M. H. MILLS, Esq., Mansfield Woodhouse, Mansfield.
 J. B. SMITH, Esq., Newstead Colliery, Nottingham.
 W. SPENCER, Esq., Southfields, Leicester.
 W. WILDE, Esq., Sheepbridge Works, Chesterfield.

COUNCILLORS.

A. G. BARNES, Esq., Grassmoor Collieries, Chesterfield.
 G. J. BINNS, Esq., Netherseal Colliery, Burton-on-Trent.
 G. S. BRAGGE, Esq., Granville Colliery, Burton-on-Trent.
 P. M. CHESTER, Esq., Oakwell Colliery, Ilkeston.
 H. R. HEWITT, Esq., 47, Hartington Street, Derby.
 J. HUMBLE, Esq., Markham Collieries, Chesterfield.
 C. R. MORGAN, Esq., Hurst Lodge, Alfreton.
 R. H. ROBINSON, Esq., Marlpool House, Derby.
 W. H. SANKEY, Esq., Morley Hall, Derby.
 T. A. SOUTHERN, Esq., Rose Hill Street, Derby.
 R. J. STRICK, Esq., Cossall Colliery, Nottingham.
 R. THORNEWILL, Esq., Engineering Works, Burton-on-Trent.
 JOHN JACKSON, Esq., Stubben Edge, Chesterfield,
 GEORGE LEWIS, Esq., Albert Street, Derby,
 J. A. LONGDEN, Esq., Teversal, Mansfield,
 HENRY LEWIS, Esq., Annesley Colliery, Nottingham,
 S. ALSOP, Esq., Pinxton, Alfreton,
 G. E. COKE, Esq., Corporation Street, Chesterfield,
 G. HEWITT, Esq., Castle Gresley, Burton-on-Trent,
 C. H. OAKES, Esq., Holly Hurst, Alfreton,

} *Past-Presidents.*} *Vice-Presidents of
previous year.**Ex-officio.*

TREASURER.

E. EASTWOOD, Esq. Railway Wagon Works, Chesterfield.

SECRETARY.

W. F. HOWARD, Esq., 15, Cavendish Street, Chesterfield.

REPRESENTATIVES ON THE COUNCIL OF THE FEDERATED
INSTITUTION OF MINING ENGINEERS.

A. BARNES, Esq.	W. F. HOWARD, Esq.	H. LEWIS, Esq.	M. H. MILLS, Esq.
G. E. COKE, Esq.	J. JACKSON, Esq.	J. A. LONGDEN, Esq.	W. SPENCER, Esq.

The CHAIRMAN said that was the last time he would take the chair at any of their meetings in the position he had occupied during the past twelve months. It had been a source of very great pleasure for him to do so, as he had the kindly support of every member of the Council and of the Institution. He felt sure that there was a prosperous career before that Institution, and he hoped it would continue to grow in numbers and in usefulness. In his successor they had a very able man, a man whose vast experience would be of great benefit to the Institution. He felt very great pleasure in asking Mr. Barnes to take the chair.

Mr. ALFRED BARNES said he was afraid he could not fill the position of President so well as Mr. Lewis had during his term of office. Mr. Lewis was a man of great capacity in the particular line of business he had taken up, the production of coal, which was of such especial value to the coal trade as a whole. It was in the highest degree necessary that the men who produced the coal should thoroughly understand their business. Mr. Lewis had had great experience, and that Institution had had the benefit of it, and he was sure if he were again asked to fill the chair he would do so as ably as he had done during the past twelve months. He thought he would himself perhaps have been spared occupying that position, as his years were increasing considerably, but, if they were satisfied, he would do the best he could during the time of his presidency. He now proposed to give them a short review of the coal trade from its earliest days :

PRESIDENTIAL ADDRESS.

BY MR. ALFRED BARNES.

In the days of Charles I., the whole of the south of England was supplied with coal from Durham and Northumberland, the only means of transporting it being by means of sailing vessels up into the Thames. The coal was obtained from day-levels and small pits, worked here and there on what they termed the "old man." They in their day sometimes found the "old man" very inconvenient. He had deluged their workings with a lot of water which they did not want. The output in 1700, as it was computed, was very small indeed.

They must remember that canals did not come into existence to any extent until 1780, that there were no turnpike roads, except the north road from London into Scotland; that all the roads were not roads, and that nobody mended them except "God and the sun," for such was the remark that an old man made to his father when asked who mended the Wingfield road. In those days they could not go on the roads to any extent except in the summer time, or when the weather was favourable, on account of the sludge and their bad condition. Consequently small local wants only were supplied, and these chiefly from day-levels, as there was no engine-power.

The quantity raised was, consequently, very small, being computed at 2,612,000 tons in 1700, but in 1743 it had risen to 4,773,828 tons.

By that period his ancestors were at work in that neighbourhood; certainly only in a very small way, a good deal of the coal being conveyed in sacks on pack-horses. He had heard his father say that his great grandfather, born in 1680, stated to his son, "John, we have had a very good year; we have made £10." They must of course, remember how the coal had to be raised and conveyed, and that the purchasing power of £10 in those days would be equal to £100 now. That being so, he did not think £100 out of a gin shaft was a bad profit. This pit was at Ashgate, and the coal worked would be the black shale or the Brampton Low coal. Since that time—with the exception of the period from 1830 until 1846, when he commenced coal-getting—his family had got coal from that day to the present. Indeed, he believed that his family were the oldest firm of coal-getters in Derbyshire, and in Nottinghamshire Messrs. Barber, Walker, & Company were the oldest. They had fortunately not now

to rely on pack-horses ; they had something better. In 1780, the output of coal had risen to 6,424,976 tons ; in 1784, to 6,888,712 tons ; in 1795, to 10,681,728 tons ; in 1800, to 10,080,300 tons, so that in a century it had risen to five times the amount. In 1815, the Waterloo year, it had risen to 27,020,115 tons. At the period when he commenced business, the end of 1846 or the beginning of 1847, the quantity raised was about 60,000,000 tons, according to a computation made by Mr. Stokes, who had more knowledge of this subject than himself. He always thought that at that time it was about 50,000,000 tons. In 1853, it had increased to 64,400,000 tons.

Supposing they took the output at 60,000,000 tons, what would be their position if the plan and the idea of some of the colliers' delegates at the present time were carried out, that no person should do any work in a coal-mine unless he had served an apprenticeship ? There would have been no increase in the output, and it certainly would not have reached 100,000,000 tons by this time. Unless they had allowed unskilled workmen to go into the collieries to do the work which he would describe as the hewing of wood and drawing of water, without taking the management of the stall, the coal trade could not have risen to what it is now. These men in time became competent ; they got from one position to another, from loaders to assistant stallmen, and ultimately to take charge of a stall. He did not suppose that any manager would knowingly allow a man who had only been in a pit a couple of years, to go into a stall and to take the responsibility of having others under him. No doubt the object was to restrict the output, but the output could not be restricted in that way. The miners' delegates wanted restrictive action so that no one could go into a pit except those who had knowledge. But they must go in to get some knowledge to begin with.

As they passed on to more recent times, they came to the period when the first Mines Act was passed in 1850, and it was from 1851, when that Act came into operation, that their statistics were correct. In 1853, the output was 64,400,000 tons, and the number of tons raised per life lost by explosions was 302,347.

Passing on to more recent times, they came to 1870, which saw the beginning of the great impetus of trade that took place through the Franco-German war, for that especially was the great factor of the good trade from 1870 upwards. During the twenty years from 1850 to 1870, there had been no development of the mines of the country of any consequence. That was because it did not pay to put any more into coal-mining ; and he had it from the very best authorities connected with the

North of England that the mines of England did not make 4 per cent. Now, if they took the risk of mining, they would see that 4 per cent. was a very inadequate return.

When the great struggle took place between France and Germany, the price of coal rose to an extraordinary height. That period of very great inflation brought a large amount of capital into coal-mining. The moment it was known that there were such large profits to be made out of coal-mining everyone rushed in, and the majority burnt their fingers.

As they passed on from that period they came to 1880, when the output was 146,835,707 tons, an advance in ten years of, roughly speaking, 34,000,000 tons. In 1885, the production was 159,242,388 tons. In 1890, it was 181,512,021 tons, and in 1891, 185,373,445 tons, but in 1892 it went back again to 181,674,990 tons.

Now, they were aware that during the impetus from 1870-75 a great outcry was raised that the coal in the kingdom would not last above a certain time, and a commission was appointed, presided over by the Duke of Argyll, and upon which Mr. Woodhouse was the commissioner for the Midland coal-field. This commission reported that the coal in the country would last for about 250 years. But they did not know then that they would be able to get into the east, nor how far, and they did not know what science would do and will do in the future, to enable them to get coal at a greater depth than 1,000 yards. He thought it was very great folly for any man to predict what would be done in the future. Science was advancing at a great pace. It was now cut up into small divisions, and whereas a man in the past embraced many subjects, he now only took a part of one. So they might depend upon this that, if coal were wanted and it only existed at a much greater depth than at present, they would be able to get it in future ages. England was not a nation to stand still. They had very able men in the coal trade, and especially in the scientific world, and whilst they had lived to see things which their fathers had never dreamed of, he believed they were on the verge of greater discoveries in the scientific world, and coming generations would find out ways and means of doing things they at present could not understand.

He remembered when railways were first opened, it was said it was impossible that the amount of money expended on them could produce an income. They knew now how foolish was that remark. It was also said that they would do away with horses. The very introduction of railways had called into use a far greater number of horses than before.

Any prediction as to the future was foolish and unwise. All they

could do was to prepare for the near future and deal with the present, and they had got a very awkward present before them just then. These were times such as none had seen before, and before they were over they would not like the realization. In 1854, they had a period of considerable depression after a similar inflation, especially in the London market, in consequence of the want of steamers and an east wind prevailing for six weeks, and leaving London almost without coal. He remembered an article which appeared in the *Times*, and which began with the very significant words, they would like to see now, "coal, £3 per ton." In that year, the Clay Cross Company were the pioneers of the railway trade to London, in fact he thought that was the first year that they went there—in 1854. They realized a very large profit per ton upon the stock they had, which was a goodish stock for those days. Then the wind changed, the ships came in, and there was a glut upon the market, with between six and seven miles of coal-trucks standing upon the main lines outside of London.

He happened to be on the Continent that year, (on the occasion of his marriage), and when he came back he found Grassmoor colliery standing still, and it stood for two months, for they could not get their full wagons emptied, and they could not get private ones; they were used as warehouses. They had to stand until the time came that they could move again. He supposed they would move again now sooner or later, but he did not venture to prognosticate what the future would be, because as he said prognostications were foolish.

He had seen a chart showing the price of coal at the ship side at the port of London from 1805 to 1877. The prices varied from 45s. per ton in 1814, as the highest price, down to 15s. in 1851, and it jumped up and down like any other chart. In 1873, it got to 30s., and the prices charged to the consumer would be about 5s. more than he had named. For two days in September, 1873, coals were quoted at 45s. per ton on the London market. Coal was sent to London by rail as early as 1845, but in very small quantities. The Clay Cross Company had a contract for 70,000 tons, and it was thought they could not carry it out at a certain rate, but they made a considerable sum of money out of it.

The total coal raised in the Midland inspection district last year was 21,587,967 tons. Of this Leicestershire raised 1,500,235 tons; Nottinghamshire, 7,159,750 tons; Derbyshire, 11,141,152 tons; and Warwickshire, 1,786,880 tons.

He did not know that he had anything more to say to them, but if he could do anything to assist or promote the welfare of the Institution he

should be glad, though he must say it rested more with the younger men to put their shoulders to the wheel. Success could only be achieved by hard work, and not by wishing alone, and if they were to have 100 more members by this time next year they would have to work to accomplish this result.

The PRESIDENT then moved a vote of thanks to Mr. Lewis for his conduct in the chair during his period of office. He would not say any more about Mr. Lewis than he had already done, because he might make him blush.

The vote being passed by acclamation.

Mr. HENRY LEWIS thanked the members for the vote of thanks, and wished them all a happy new year. He felt confident that with their new President, the new year would be most successful.

Mr. GEORGE LEWIS said the members' thanks were due to Mr. Barnes for his interesting address, to which he must have devoted much time and care. His address had referred them to the coal trade as it existed in 1660. In reference to this, he might mention a circumstance connected with a colliery with which he was acquainted, and worked by Messrs. Nadin & Co., which was working in 1550, a hundred years earlier. They proved this from the fact that at that date royalty was staying at Tutbury castle, that these gentlemen supplied coal for their use, and that the account was said still to remain unpaid, as shown by the colliery ledgers. He had very great pleasure in proposing a hearty vote of thanks to the President for his address.

Mr. LONGDEN seconded the resolution, and was sure that the reminiscences they had listened to were extremely interesting. He could not help thinking during the address what a good thing it was for them to have a change of President each year, as each presented different views and ideas. The address of Mr. Barnes would be a very valuable addition to the records of the Institution.

The CHAIRMAN briefly replied, and made a jocular allusion to the ease with which "the gentlemen of the Leen valley" were able to produce coal.

The PRESIDENT expressed to Messrs. C. F. V. Ford and G. F. Hirst, the thanks of the meeting for their services as scrutineers.

Mr. A. H. STOKES communicated the following paper on "A Safety-lamp with Standard Alcohol-flame Adjustment, for the Detection and Estimation of Small Percentages of Inflammable Gas":—

A SAFETY-LAMP WITH STANDARD ALCOHOL-FLAME
ADJUSTMENT, FOR THE DETECTION AND ESTIMATION
OF SMALL PERCENTAGES OF INFLAMMABLE GAS.

By A. H. STOKES.

INTRODUCTION.

The bringing forward of a new description of safety-lamp might command little interest or criticism, seeing that alterations, modifications, and new designs of safety-lamps are legion; but, with few exceptions, the writer believes that all arrangements or new designs of safety-lamps have been devised with a view to increased safety or better illumination.

Within the last few years more attention has been given to the causes which appear to have materially influenced and extended the effects of an explosion of gas in a mine. Experiments have demonstrated that a mixture of air and gas, which would not show the presence of gas when tested by the ordinary safety-lamp, may become an inflammable mixture if it be more or less charged with coal-dust. Thus, where formerly mining engineers were satisfied with the air-currents of a mine, provided no gas cap could be detected with a small oil-flame, they now desired to ascertain not only small percentages of gas in the return currents, but to measure the percentages by photometric or flame-cap tests, with almost the accuracy of ultimate chemical analysis.

It must be quite clear to all that no practical tests which can be made by the ordinary colliery official during his round of inspection, will be equal in accuracy to those made by the analytical chemist. Colliery officials' tests must be, at the best, only approximate, and will but approach accuracy in proportion to the precision of the apparatus used, and the correctness of the observation. The testing of air-currents in the mine by either photometric or flame-cap tests must depend largely upon good eyesight and memory for comparisons.

Several fire-damp indicators have been proposed, some of them of highly scientific construction, and influenced more or less by the density of the gas and temperature of the atmosphere. Others are so complicated in their manipulation that none but persons possessing considerable scientific skill can use them. It is only those indicators which depend upon the combustibility of fire-damp that up to the present can be

practically used by ordinary colliery officials. Such officials are trained observers of the blue flame due to the combustion of fire-damp; they are daily searching for such indications, and approximately judge the quantity of gas, when found, by the greater or less extent of blue cone appearing above the oil-flame of the safety-lamp.

The volume of fire-damp which may be disengaged from the working-face of a mine and passing into the return air-current is, no doubt, very variable, and may be influenced by the rate at which the coal is freshly cut. The exudation may not only take place over the whole face of the coal-seam, but may be influenced by the permeability of the roof and floor of the seam.

There can be little doubt that it would be desirable to test daily and record the state of the return airways of a mine with respect to inflammable gas. If such tests could be carried out with the officials' ordinary safety-lamps, or without carrying cumbersome apparatus, there would be little difficulty in educating the official to his work, and obtaining the daily record by ascertaining the proportion of fire-damp in the various divisional return airways, or determining the nature of the atmosphere issuing from, or contained in, old workings; thus following, day by day, the extent of exudation from the working-faces, or variations in the composition of the air returning from the workings or old goaves, or at any point that it may be desirable to watch with special attention. By this means a knowledge would be obtained of the quantities of fire-damp disengaged, either in the whole of the mine or from its different points.

DESCRIPTION OF LAMP.

This safety-lamp (Fig. 1, Plate XVI.) is a modification of the Gray type, one of the four lamps recommended by the Royal Commission on Accidents in Mines. The lamp is specially designed and arranged as a gas-tester or officials' lamp; the poles or standards being hollow tubes, so that the inlet-feed can be taken from the top of the lamp, thus enabling the test to be made as high as the top of the lamp can be placed. The glass is made considerably longer than the ordinary glass, so that the length of the gas-caps can be measured, but it is less in diameter than that attached to the ordinary Clanny type of lamp, so that in high percentages of gas the amount of explosive mixture contained in the lamp, and which may be fired inside the lamp, is reduced to a minimum. The full length of the glass, for a breadth of 1 inch, is enamelled jet-black to form a black back-ground or screen for more clearly detecting the cap due to small percentages of gas. In making test observations this black back-ground

should always be held behind the light, be it the ordinary oil flame or the alcohol tester, and the writer has found it advantageous, before making delicate tests, to smoke the inside of the lamp-glass with a lighted taper for the full width of the black band previous to taking it into the mine, thus making the band more of a dead black than the enamelled black of the glass.

The lamp bottom (Fig. 2) is provided with a small tube *b* passing through the oil vessel similar to a pricker tube, but of larger diameter. This tube is fixed immediately behind the wick-holder of the oil flame, and terminates on a level with the top of the wick-tube *a*. The bottom end of this tube terminates in a sunken circular cavity in the bottom of the oil-vessel, such cavity being closed by a screw-plug *c* when the tester is not in use. The upper portion of the tube or that inside the lamp-glass, and behind the wick-tube, is protected by a spring-cap or extinguisher *g*, which opens to receive the tube of the alcohol tester, and closes upon its withdrawal. This is so arranged that the mouth *g* of the tube *b* cannot be opened unless by the insertion of the alcohol tester, and the tester cannot be withdrawn without the tube *b* being closed, the opening being firmly closed before the alcohol testing-vessel is unscrewed from the thread of the plug cavity. From this it will be seen that no flame can possibly pass down the tube *b*, even if the official using the lamp omitted to replace the screw-plug *c*, after making a test for a low percentage; but a further precaution is taken by attaching the screw-plug to the lamp by means of a short chain. If the plug be loose, and the official had to put it in his pocket when about to use the alcohol tester, he might forget to replace it, but as it is permanently attached by a chain the plug hanging loose below the lamp bottom would remind him of his omission.

The alcohol tester (Figs. 3 and 4, Plate XVI.,) consists of a small cylindrical brass vessel for containing the alcohol, with a long wick-tube *i* screwed into the top of the vessel, the connexion being made by means of a circular brass plate, on the under side of which is a leather washer to ensure a perfect fit. The wick-tube is only 4 millimetres (0·16 inch) in diameter, and 55 millimetres (2·20 inches) long, burning with two strands drawn from the ordinary round wick used for an oil-lamp. The wick-tube *i* when not in use is protected from injury by a cap or covering *f* (Fig. 3) which, when placed over the wick-tube, is screwed to the alcohol vessel. The bottom of this cap is provided with a leather washer, securely covering the air-hole of the alcohol vessel; the screw of the covering does not screw home or touch the vessel, and in this way brings the screw pressure to bear upon the leather washer. The two leather washers securely close

the alcohol vessel, so that it may be carried in the waistcoat pocket without fear of any of the alcohol escaping.

The tester is charged with pure alcohol before being taken into the mine, and when fully charged will burn for about four hours. This time permits of 120 tests of two minutes each being made before the alcohol tester requires to be refilled.

MODE OF TESTING.

The alcohol-flame is not intended to be used for the ordinary mode of examination of the working-places, but should only be used after the oil flame of the safety-lamp has failed to detect gas; or in other words, examination with the alcohol-flame commences where the oil-flame breaks off.

The official using the lamp should first test with a reduced oil-flame, and if this fails to indicate the presence of gas, he then raises his oil-flame to its normal height. The screw-plug *c* is then withdrawn from the bottom of the lamp and the alcohol tester made ready by unscrewing the cap *f* and seeing that the wick has been cut level with the top of the brass tube *i*, it is then inserted through the bottom of the oil vessel and screwed tightly up. The top of the alcohol wick-tube *i* will have opened the spring cap *g*, and appeared above the same. In a few seconds the heat of the oil-flame will have caused the alcohol to ascend the wick-tube and become ignited, or the lamp may be held a little on one side, so that the light from the oil-wick ignites the alcohol-wick. The alcohol-wick being lighted, the oil-wick is drawn down into its wick-tube and so extinguished. We have then only the small pale blue flame of the alcohol tester burning inside the lamp, and by which the test is then made. Should no gas cap appear above this flame, the atmosphere may be considered as virtually free from inflammable gas, or containing below 0.50 per cent. of gas. Should a gas cap appear, its intensity of colour and length gives the percentage of gas contained in the atmosphere.

The testing is materially facilitated by placing a small slip of black cardboard round the front of the glass, of sufficient depth to cut off from view the whole of the alcohol-flame, and long enough to be held by the two standards of the lamp when placed between such standards and the glass.

The test being made and noted, the oil-wick is raised by the pricker and bent over until it touches the alcohol-flame, and is re-lighted by the same, the flame is then adjusted to its proper light-giving height and the alcohol vessel and wick-tube unscrewed. The withdrawal of the

alcohol wick-tube *i* enables the automatic spring-extinguisher *g* to close the opening of the insertion tube *b* inside the lamp, and on the screw-plug *c* being inserted the lamp assumes its normal form, and is again an ordinary safety-lamp with oil-flame. The cap or cover of the alcohol wick-tube *f* is screwed on, and the apparatus placed in the pocket until further required for use, its weight being about $4\frac{1}{2}$ ounces.

In the case of air-currents containing 3 per cent. or more of inflammable gas, the alcohol-flame is superseded by the ordinary oil-flame, inasmuch as that proportion is clearly visible in ordinary oil lamps, and therefore the alcohol-flame is not used for these high proportions, which could only be obtained by sacrificing the efficiency of the test for the proportions lower than 3 per cent.

Any person accustomed to testing for gas in a mine will have little difficulty in using the alcohol tester and ascertaining with approximate accuracy the percentage of gas contained in the atmosphere of various parts of a mine.

TESTS.

The writer has made many and varied tests and alterations in construction to produce a lamp that would answer the double purpose of an ordinary safety-lamp and a gas tester; and such tests could only be satisfactorily conducted under conditions which would ensure accurately measured percentages of inflammable gas and air. The writer knows of no better apparatus for making such tests than the one designed by Dr. Clowes, which has been already described in the *Transactions*.* By the courtesy of one of the writer's colleagues, he obtained the loan of such an apparatus, and the whole of the tests have been made in it. The writer would wish to bear testimony to the valuable and simple apparatus designed by Dr. Clowes for trying safety-lamps in measured percentages of gas and air, and to acknowledge his indebtedness to such an apparatus for testing and perfecting his alcohol flame-tester.

The gas used was ordinary coal gas, and the quantity was carefully measured and mixed before the tests were made. In testing very low percentages a little difficulty was experienced by having to view the very pale blue cap through two thicknesses of glass, viz., the glass of the safety-lamp, and the glass of the mixing apparatus, but many tests were made with the naked alcohol-flame in the apparatus, and viewed through only one thickness of glass.

The testing for low percentages of fire-damp required a little training in observation, for the cap is so very pale in colour, and the thick circular

* *Trans. Fed. Inst.*, vol. iv., page 441.

lamp-glass so detrimental to the observation of such caps, that it required very careful sight-searching, assisted by all the artificial adjuncts available (such as shading the light, and using the black back-ground) to clearly detect the very pale blue cap due to very low percentages of fire-damp. But this cannot create surprise when we consider the very small quantity of gas necessary to form such mixtures ; in fact, in testing on the surface, a naked light may be introduced without fear of explosion in the whole of the mixtures for which the alcoholic flame is intended to be used.

The indications, though less precise than the ultimate analysis of the air-current, have the great advantage of being obtainable in the mine, and by any person of ordinary intelligence.

The following are the results of the tests made by the writer :—

ALCOHOL-FLAME, WITH A STANDARD HEIGHT OF 13 MILLIMETRES (0·52 INCH).

Percentages of Gas.	Height of Standard Alcohol Flame.	Height of Gas Cap.		Remarks.
		Millimetres.	Inches.	
0·5	13	15	0·60	Very pale, not clearly seen.
1·0	„	25	1·00	Pale blue colour, can be clearly seen.
1·5	„	36	1·44	Pale blue colour, clearly defined.
2·0	„	42	1·68	Clear blue-coloured spiral.
2·5	„	50	2·00	Distinctly defined gas cap.
3·0	Oil flame.	—	—	

The top of the cap is, in all cases, so thin and attenuated that its termination for measurement requires careful observation.

In conducting tests on the surface it is absolutely necessary that they should be made in a perfectly dark room, darkness equal to that which would be found in a mine.

With 0·5 per cent. of gas, the gas cap is very pale blue in colour, conical in form, and can only be observed by carefully shading the light of the alcohol flame. It is with difficulty measured, owing to the top part of the spiral cap being so attenuated and of so pale a colour.

With 1·0 per cent. of gas, the gas cap is pale blue in colour, it can be clearly seen, and shows a defined spiral shape, which can be measured by shading the light of the testing flame.

With 1·5 per cent. of gas, the gas cap is of a pale blue colour, but of a little deeper colour than with lower percentages, and is distinctly defined.

With 2·0 per cent. of gas, the gas cap is a clear blue-coloured spiral of the well-known description of cap due to inflammable gas.

With 2·5 per cent. of gas, the gas cap is in colour similar to the cap obtained in the previous test, but very distinct and well defined.

CONCLUSIONS.

1.—The lamp is an official's ordinary safety-lamp, and therefore can be used for light, and for the daily work of examining and testing the mine.

2.—The alcohol tester is simple, easily applied, and can be carried in the waistcoat pocket.

3.—The alcohol tester should not be used as a primary light for finding gas in goaf, or in holes, but for detecting low percentages of gas after the ordinary oil-flame has failed to indicate its presence.

4.—When making a test the flame of the alcohol-burner should be shaded from sight by a piece of cardboard or the palm of the hand.

5.—The colour and length of the cap should be noted, and unless the observer is an expert in testing, the notes made in the mine should be compared with the copy of standard flame tests for determining the percentage of gas in the atmosphere.

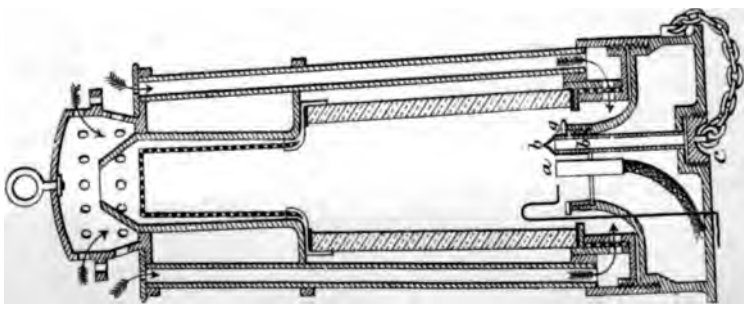
6.—The standard size of alcohol-flame is not immediately obtainable by introducing the tester when the lamp is cold; but after the lamp has been burning some little time the oil vessel becomes warm, due to the heat from the oil-flame. If the alcohol tester be then introduced it gives in a few seconds the standard height of 13 millimetres or 0·52 inch.

The PRESIDENT enquired if the lamp could be used to test for testing in the presence of more than 3 per cent. of gas.

Mr. STOKES said that it was unnecessary to use the alcohol-flame for testing 3 per cent. and upwards of gas, the oil-flame was intended to be used for all ordinary examinations and tests. Pure alcohol was used, costing 5d. per ounce, and the amount of alcohol contained in the receiver would make about 120 tests, and should burn continuously for about 4 hours. The cost of the alcohol for that number of tests or time would be about 2½d. Methylated spirit could be used, but its results were much inferior to those given by pure alcohol, and it burnt with a slightly yellow flame.

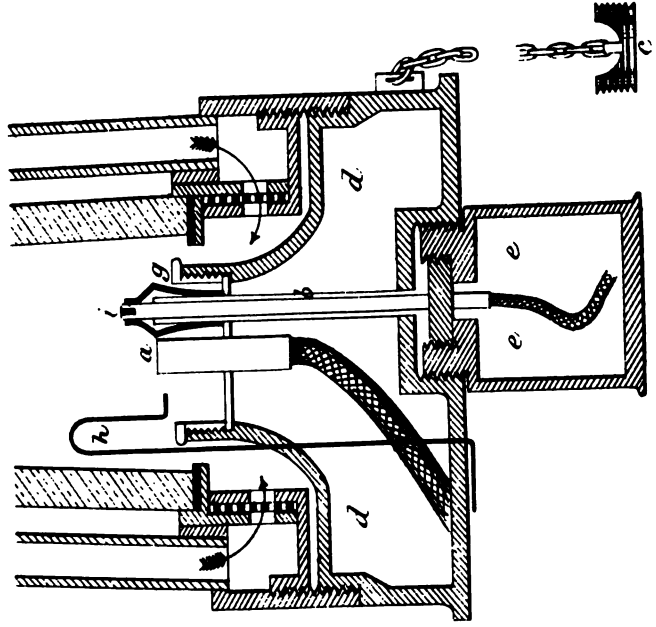
To illustrate Mr. Stokes's Paper on "A Safety-lamp with Standard Alcohol Flame Adjustment &c."

FIG. 1.



Scale 1 Foot to 4½ Inches

FIG. 2.



Scale 1 Foot to 9 Inches

FIG. 3.

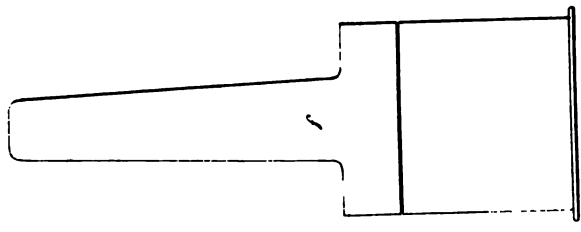
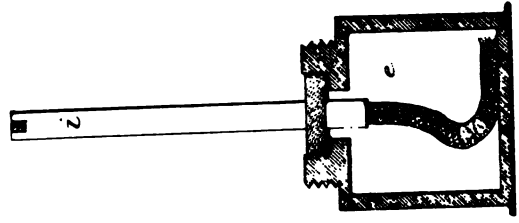


FIG. 4.





Mr. ALFRED CHAMBERS said if the test by the alcohol-flame be accepted as a distinct advance on the system hitherto adopted of testing by the oil-flame which does not give a definite result, neither in the stalls or main roads (intakes or returns). The percentage test is the only satisfactory and scientific one, together with a daily report of the percentages of gas in each current; the finding of gas in isolated lodgments in moderate quantities is of secondary importance to a knowledge of the diffusion of explosive gas at different points in the mine as well as at the points of the confluence of currents in the return airways. Taking a prospective view of the alcohol test, the ultimatum must be a primary one; the alcohol and oil-lamp must be duplicated for ordinary convenience.

Mr. STOKES said that the tests should first be made with the oil-flame, and if no gas indication were found then with the more delicate alcohol-flame. The lamp would principally be of service to test return air-currents. Such fine tests had arisen lately in consequence of the theory that small percentages of gas mixed with coal-dust were inflammable. He was not a great advocate of the extreme dangers of coal-dust, but he always admitted that coal-dust influenced explosions and extended them. He, however, had not yet heard of an explosion of coal-dust taking place in a mine where gas had never been found. If they had a coal-dust-laden atmosphere with a small percentage of gas it might become an explosive mixture. The alcohol-lamp was intended to assist in detecting small percentages of gas in the return air-currents of a mine. When the deputy had finished his examination of the working-places, he should test the return air-current from his district. He should first test the air with the ordinary oil-flame, and if he found no traces of gas he would then use the alcohol-flame and note the result. The alcohol-flame was not intended for primary tests, and was only to be used where the oil-flame had failed to detect gas.

Mr. JOHNSON PEARSON asked if the primary test with the oil-flame were neglected, and the alcohol-flame used for testing where there was a higher percentage of gas than 3 per cent., would that be a source of danger?

Mr. STOKES explained that the Pieler lamp had been taken as a basis for his lamp, but the flame caps were very large in the Pieler, and were a great source of danger in high percentages of gas. The alcohol-flame in his lamp was very small and he knew of no danger in testing a mixture containing above 3 per cent. of gas, if anyone desired to use it for such mixtures.

Dr. CLOWES was gratified to know that his test-chamber had once

more proved itself of value in carrying out a series of tests as to the delicacy of a gas-testing apparatus. He could state, after a careful examination of the different forms of apparatus designed for the same purpose, that his test-chamber was the most simple, efficient, and economical apparatus available, and had proved itself to be such in the hands of many different operators. Reference had been made to the necessity of testing for very low percentages of gas, since these low percentages, though non-explosive in themselves, became explosive in the presence of coal-dust. The necessity was also rightly insisted upon of detecting and measuring minute proportions of gas, in order to gain an idea of the rate at which gas was issuing from time to time; and to form an opinion as to sufficiency of the ventilation current, and of its distribution to meet the variable gas-issues. The tendency at present was to insist upon the necessity of very accurate and delicate testing. Mr. Galloway had proved this test to be requisite by showing that less than 1 per cent. of gas was explosive in the presence of coal-dust. Those who are most competent to express an opinion insist, therefore, that a testing instrument must detect and measure accurately a percentage of gas as low as $\frac{1}{2}$, and even as low as $\frac{1}{4}$. An apparatus which cannot accomplish this result cannot be in the first rank; and it cannot afford a guarantee of safety, or properly gauge the condition of the airways. According to his (Dr. Clowes') experience the alcohol-flame, as applied by Mr. Stokes, was by no means so well adapted as the hydrogen-flame, to secure delicate and accurate testing. In the course of many experiments made with such an alcohol-flame, it was found to be variable, and could not rank as a standard, or give standard caps. Further, under the most favourable circumstances, 1 per cent. of fire-damp was the lowest percentage indicated by this flame, and the cap produced by this percentage was very pale. The alcohol-flame, although it was much paler than a reduced oil-flame, diffused sufficient light throughout the lamp to interfere with the observation of pale caps. It was also found that the small alcohol-flame was easily extinguished, when the lamp was exposed to air-currents such as it was frequently subjected to in the pit; and that it was very liable to be extinguished by impurity in the air. To these objections may perhaps be added that raised by many practical men, that volatile spirit should not be burnt underground; an objection to which, however, the speaker attached little weight, if proper precautions were taken. The lamp-glass itself formed a serious impediment to the observation of pale caps. This was partly owing to its curved surfaces, but was largely due to a film which settled on the inside of the glass, after the flame had been burning

for a short time. Any observations made in the test-chamber with the naked flame were therefore illusory; since the flat window of the chamber exerted no such hindrance, as the lamp-glass did, to the passage of the light, and could not be looked upon as in any way representing the lamp-glass. And of course the use of a naked flame for testing in most positions underground was quite impossible and inadmissible. He (Dr. Clowes) was at a loss to explain how Mr. Stokes had seen and measured a cap given by $\frac{1}{2}$ per cent. of gas, since he had absolutely failed to effect this with such an alcohol-flame, when the lamp-glass was used. The employment of coal-gas instead of methane (fire-damp) would tend to make the cap more visible; but even this gas had failed in his tests to show a cap. A series of tests in the test-chamber, carried out in the presence of members of the Institution, would decide this difference of experience of himself and of Mr. Stokes. The introduction of the broad tube connecting the interior of the lamp with the air, and through which flame could pass if it were open, might be a serious source of danger if any accident occurred to the automatic cap while the lower plug was out. Mr. James Ashworth's benzoline lamp afforded a good light, and was at least as delicate and accurate in its indications of gas as the lamp proposed by Mr. Stokes. It had, further, the advantage of greater simplicity of construction and of greater safety; and burnt one flame and one liquid instead of two. He was at a loss to see in what respect Mr. Stokes could claim that it should be replaced by the alcohol-lamp. According to his (Dr. Clowes') experience, neither lamp stood in the first rank as a detector and measurer of gas, either for accuracy or delicacy. Surely, in the light of the present knowledge as to the requisites for securing the safety of the mine, the most delicate and accurate practical gas-testing apparatus was the one to be preferred.

Mr. STOKES said he gave Dr. Clowes every credit for his test-chamber. Had it not been for that apparatus for mixing small percentages of gas and air they would not have heard him (Mr. Stokes) or seen the lamp there that day. He did not know—and this he had said in his paper—any mixing apparatus so scientifically useful, so neat, so cheap, or so easy of manipulation as that designed by Dr. Clowes, who very kindly offered to lend him the use of one at the Nottingham University College, but he could not accept this kindness because he had a lamp of his own. His tests had, however, been made in a similar apparatus with the alcohol-flame inside the safety-lamp and therefore inside the glass.

Mr. H. LEWIS hoped that discussion would be adjourned until they had read the paper in the *Transactions*. The lamp struck him as being a

safe one, but he thought the extinguisher might be unsafe, though Mr. Stokes had assured them it was not a weak point.

The PRESIDENT said it was very desirable to know the exact percentages of gas in the various returns of a pit. He agreed with Mr. Lewis that the discussion of the paper should be adjourned.

Dr. CLOWES said that, in his experiments with hydrogen and with alcohol, he found that the gas caps over the flame of the former were more clearly visible than those over an alcohol-flame.

The PRESIDENT moved a vote of thanks to Mr. Stokes for his paper, and the discussion was adjourned.

Mr. H. R. HEWITT (Derby) wrote that he had been present on several occasions during the experiments with this lamp, and could fully endorse the statements made by Mr. Stokes with regard to it. With 1 and 2 per cent. of fire-damp, the caps were plainly visible, and the test was highly successful for these percentages. With $\frac{1}{2}$ per cent., the cap was visible when the lamp was placed in the gas in a naked condition, but it was highly probable that it would be distinguished with difficulty when seen through the lamp in its working condition. The lamp-glass was, he thought, of the best possible shape to ensure good results, but its great thickness (which was however unavoidable) was a drawback to the approximation of small percentages. The Chesneau fire-damp indicator appeared to be highly complicated, and required some considerable amount of practical acquaintance before it could be used with any degree of accuracy.* Mr. Stokes' lamp and the Chesneau indicator were fed with alcohol, and it must be remembered that lamps fed in that way had a greater tendency to rust and injure the gauze than lamps fed with either hydrogen or colza oil. The indications of gas in the Chesneau detector are seen through a thin plate of mica, which must be disadvantageous to an accurate indication. During the experiments ordinary lighting gas as supplied by the Derby Gas Light and Coke Company was used of the following composition:—

	Per Cent.
Olefiant gas and gases of the olefiant series ...	6·0
Marsh gas... ..	34·5
Hydrogen... ..	46·0
Carbonic oxide	7·0
Carbonic acid	3·5
Nitrogen	2·5
Oxygen	0·5
	100·0

* *Trans. Fed. Inst.*, vol. 1v., page 617.

According to Sir L. Playfair ordinary inflammable gas as found in the Jarrow colliery was composed as follows :—

	Per Cent.
Marsh gas	83·1
Nitrogen	14·2
Oxygen	0·6
Carbonic acid	2·1
	100·0

It will be observed that there was a considerable difference in the composition of the gas used and natural gas, and the question appeared to be, were the experiments made under these conditions as reliable as they would have been had fire-damp been used? Respecting this Mr. Chesneau says with regard to his own experiments :—

To exactly fulfil the conditions which occur in practice it would have been better to have experimented with natural fire-damp, but when this cannot be obtained I see no reason why methane should be employed, as fire-damp is not pure methane. Sometimes the hydrogen which it contains makes it more inflammable than methane, while rendered impure by carbonic acid and nitrogen it loses much of its sensitiveness; besides it is proved that with lighting gas of medium composition mixtures are obtained, the explosibility of which is not less than that of most samples of fire-damp. Moreover, it has been proved that air containing 10·5 per cent. of this gas is practically as dangerous as the most explosive mixture of fire-damp and air.

So that it might be concluded that experiments made with ordinary illuminating gas were as nearly accurate as possible, and were sufficiently reliable to guide us in making examinations of underground working-places and return airways for minute percentages of inflammable gas. He would like to know if Mr. Stokes had tried this lamp in a dust-laden atmosphere containing fire-damp, as he understood that Prof. Clowes' lamp was of little use under these circumstances? If this lamp overcame the difficulty of testing the atmosphere of roads impregnated with coal-dust it would be of very great importance. The French Commission on Explosives stated that "laboratory experiments have not permitted of noticing any appreciable difference in the inflammability of mixtures containing more or less humidity," but he would like to know if the temperature of fire-damp exposed to this lamp affected the flame cap in any way, and if so to what extent?

Mr. STOKES read the following paper on "An Improved Water-gauge" :—

AN IMPROVED WATER-GAUGE.

BY A. H. STOKES.

Many members of this Institution have, no doubt, frequently met with difficulty in reading the amount of water-gauge due to fan or furnace ventilation, and especially where the upcast shaft is used for winding coal. The opening and shutting of the pit-top, and the running of the cages cause a vibratory motion of the water in the glass tube which renders it difficult to strike the mean height, and this difficulty is further increased in proportion to the length of difference in the water-level, the eye having occasionally to travel 3 to 4 inches, and to watch the oscillations in both legs of the water-gauge simultaneously, and strain itself to judge the mean of the oscillations. The difficulty is not in any way diminished by the frequent necessity of using a safety-lamp, and of reading the water-gauge in semi-darkness.

It was thought that by contracting the bend of the glass tube, which forms the legs of the water-gauge, and reducing the connexion or passage for water between the tubes, the water-column would be steadied, and thus the oscillations due to varying pressures be avoided, or at least so reduced that the eye would easily strike the mean. The writer believes that this idea was due to Mr. John Daglish, who considerably improved the water-gauge, as first designed by Dr. Lind. There still appeared an opening for further improvements, and the small difficulties met with in the use and correct reading of the instrument having been placed by the writer before Mr. Henry Davis, of Derby, he has made a water-gauge which appears to meet many of the objections to the old description of instrument, and which forms the subject of this paper.

Description.—The water-gauge (Figs. 1 and 2) consists of two parallel glass tubes inserted into a hollow brass pedestal at the bottom with a connexion or water passage between the tubes. In the centre of the brass pedestal is a tap B with a small hole or passage through it; this tap takes the place of the reduced bend in the Daglish form of water-gauge. It is difficult to obtain a continuous glass tube having a U-shape with a small hole or contraction of uniform size in the bend, but there is no difficulty in making or retaining the hole in the brass tap of a standard uniform size.

The hole through the tap forming the water connexion between the glass tubes is so small that the oscillations due to varying pressure are considerably less than in the Daglish form of water-gauge. The throttling of the passage whilst offering a resistance to quick vibratory motions, still affords a sufficiently free connexion between the two columns of water.

Registering the Water-gauge.—It is no unusual occurrence for two persons reading the height of water-gauge to differ in their reading, especially if the water-gauge be fixed in a dark fan-drift, and read by the light of a safety-lamp. With the improved water-gauge, the height can be registered by simply turning the brass tap B when the connexion between the tubes is cut; and the height of water due to the ventilating power is fixed until the tap is re-opened, and the connexion again made. Thus when the water-gauge measurement is required in a fan-drift or other dark or inconvenient place, the tap closes the passage between the tubes and registers the difference between the two columns of water; afterwards the water-gauge is brought out



FIG. 1.

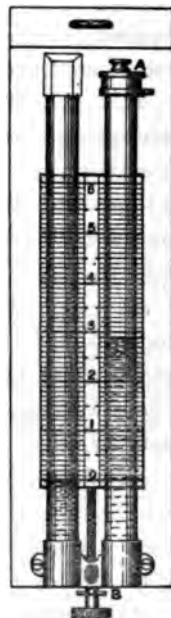


FIG. 2.

to daylight, where an opportunity is afforded to any number of persons of reading the height with the best of light, and of agreeing upon the measurement to be recorded. The closing of the connexion and registering of the water-column may also be used for ascertaining the maximum and minimum oscillations of the water-gauge due to the doors at the top of the upcast pit being opened when winding; the closing of the tap enabling the observer to make numerous records that can be read without haste and in a good light; while such observations with the Daglish form of water-gauge would have to depend upon the quickness of the eye, and be made frequently in very poor light.

Scale.—In the Daglish description of water-gauge, the scale was placed in front of the glass tubes and partly covering the tubes on either

side. This rendered it difficult to correctly ascertain the height of water owing to the concave form of the surface of the liquid in the tube due to capillarity. In the improved water-gauge the scale is placed at the back and for the full width of both tubes, and thus each black-division line of the scale cuts directly across each tube, and in this way allows the sight to observe the mean height across the whole width of the water-surface in the tubes. In ascertaining the line of water-surface in either tube, the gauge should always be held level with the line of sight of the observer. In making fan experiments, or where great accuracy of reading is required, the observer may use a magnifying glass to ascertain the water-level in relation to the divisions upon the scale.

Filling the Water-gauge.—The general mode of charging the Daglish water-gauge with water is to turn it on one side, and pour the water through the small hole of the brass connexion. Those who have made this operation will know that it is somewhat inconvenient to pour water down a small hole from which air is issuing. In the improved water-gauge the top of one tube is closed with a brass cap, having a small hole in the top. When required to be charged with water, the cap A is unscrewed and the water is poured down the glass tube to the required height, whilst the gauge is held in a vertical position. This operation is done with ease, and then the brass cap is screwed on and the gauge is ready for use.

Glass Tubes.—In the old water-gauge the tubes were all in one piece, and therefore the breakage of one necessitated the destruction of the other. In the improved water-gauge the tubes are quite distinct, and being made of parallel glass tubing one or both may easily be renewed.

Advantages.—The writer considers that the improved water-gauge has the following advantages :—

1. Simplicity of construction and ease of repairs.
2. Registration of the water-gauge by means of a tap between the tubes.
3. Easy mode of charging with water.
4. Scale at the back and extending the full width of the tubes.

— — —

The PRESIDENT moved a vote of thanks to Mr. Stokes for his paper, which was approved, and the meeting terminated.

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The following notes record some of the features of interest seen by members at the Grassmoor collieries, which were, by kind permission of the owners, visited before the Annual General Meeting, held on July 1st, 1893 :—

GRASSMOOR COLLIERIES.

The Grassmoor collieries are situated on the Chesterfield and Mansfield turnpike road, and are three miles distant from Chesterfield station, proceeding in a south-easterly direction.

They are connected to the Midland main line by the Pilsley branch, and to the Manchester, Sheffield, and Lincolnshire Railway by the new Chesterfield-to-Heath branch.

There are four drawing shafts, three of which are downcast and one upcast.

No. 1 PIT.

The No. 1 pit, 16 feet in diameter, is 1,350 feet deep to the black shale seam. The winding engine has two cylinders, 30 inches in diameter and 5 feet stroke, fitted with the Owen & Oliver steam reversing-gear, and a parallel drum, 18 feet in diameter, fitted with a steam brake as well as a foot brake. Double-decked cages are used with two tubs on each deck. The head-gear is made of wood, and the pit-bank is enclosed, as it is connected with the fan-drift and forms the upcast shaft.

The whole of the coal is at present banked on the bottom deck, from whence it is tipped on to the picking-band, which is 160 feet long and 4 feet wide where the dirt is picked out ; and all the coal is delivered at the far end into trucks. Upon this belt, travelling at 70 feet per minute, 600 tons of coal and slack can be dealt with in $8\frac{1}{2}$ hours.

An engine, with two cylinders, each 16 inches in diameter, worked by compressed air, hauls the coal from the dips by means of a single rope, the empty tubs drawing the rope in-bye on the return journey.

There are eight boilers, working at 100 lbs. pressure, supplying steam to the winding engine, fan engine, No. 3 engine, two donkey pumps, and the motive power for driving Nos. 1 and 2 picking bands.

No. 2 PIT.

The No. 2 pit is 10 feet in diameter, and 810 feet deep to the main soft seam. The winding engine has two horizontal cylinders, each 22 inches in diameter, 4 feet stroke, fitted with hand gear, and a parallel drum, 12 feet in diameter, fitted with foot brake. Double-decked

cages are used, with one tub on each deck. Steam is supplied from two boilers working up to 70 lbs. pressure. The head-gear is of wood, the pit bank is covered, and the pit acts as a downcast.

The coal is banked on both decks, and is taken by chain conveyors to the bank of the picking-band (which consists of two belts); where it is weighed and tipped on to the picking-band, the dirt being here picked out, the coal going forward to the end of the belts, where it is delivered into trucks. The belts travel at a speed of 45 feet per minute.

No. 3 PIT.

No. 3 pit is 10 feet in diameter, and 810 feet deep to the main soft seam. The horizontal winding engine has two cylinders, each 28 inches in diameter and 4 feet 6 inches stroke, is fitted with hand gear, and a parallel drum, 12 feet in diameter, fitted with foot-brake, works a double-decked cage with one tub on each deck; a second drum is also used, to which is attached a balance rope, which runs in the shaft and is boxed off. The head-gear is of wood, the pit bank is open, and the pit acts both as a downcast and a pumping shaft.

The coal is banked on the ground level, and is taken by a chain conveyor up an incline to the old No. 2 pit bank, where it is weighed and tipped on to fixed screens, and thence filled into trucks.

Steam is supplied from the boilers at No. 1 pit.

No. 4 PIT.

The No. 4 pit or Blackshale pit is 15 feet in diameter, and 1,350 feet deep to the black shale seam. The horizontal winding-engine has two cylinders, each 36 inches in diameter and 6 feet stroke, fitted with the Owen & Oliver steam reversing-gear, and a parallel drum 21 feet 6 inches in diameter fitted with a steam brake, works double-decked cages with two tubs on each deck. The head-gear is of iron, the pit bank is covered, the pit being used as a downcast. The whole of the coal is at present banked at the bottom deck level and passes over fixed screens into trucks. The whole of the slack produced is carried by Ley pan conveyors to the coal-washing machinery.

Steam is supplied from ten boilers working up to 80 lbs. pressure. An engine with two cylinders 14 inches in diameter fitted with Fisher & Walker rope-wheels and clutches works three endless-ropes, one reaching 2,000 yards in-by. Fisher clips are in use, the ropes passing under the boxes.

FAN ENGINE.

A Guibal fan, 36 feet in diameter and 12 feet wide, ventilates the whole of the seams, exhausting about 260,000 cubic feet of air per minute under a water-gauge of 2·7 inches, and is now running at 54 revolutions per minute. The fan is driven by a horizontal tandem compound condensing engine of 200 indicated horse-power, coupled direct to the fan shaft. The fan is connected to the upcast or No. 1 pit by a drift. Steam is supplied from the boilers at No. 1 pit.

AIR-COMPRESSORS.

The air-compressing engine has two horizontal air-cylinders, each 30 inches in diameter, placed behind the steam cylinders which are 26 inches in diameter. The air is compressed to 50 lbs. per square inch and supplied to the underground engines by means of a pipe 12 inches in diameter taken down No. 4 pit, branch pipes being connected at the various seams as required. It is worked by steam from the boilers at No. 4 pit.

COKE-OVENS.

The coal is elevated, washed, and crushed, after which it passes to the 180 ovens, all of beehive form. The whole of the machinery is driven by an engine with two cylinders on one shaft, one of which is 20 inches in diameter and 3 feet stroke, and the other 18 inches diameter and 3 feet stroke. The steam is supplied from the boilers at No. 4 pit.

BRICK-WORKS.

There are two Schofield machines and two Fawcett presses, producing semi-plastic bricks, which are burnt in ordinary open-topped kilns. The two machines make from 12,000 to 15,000 bricks per day of 8½ hours.

GAS-WORKS.

The gas-works produce gas for consumption on the works, all the pits and the surface works being supplied. There are three benches of retorts, the gas-holder, 40 feet in diameter, having two 12 feet lifts. The works are fitted with scrubbers, washers, condensers, exhausters, and purifiers, etc.

LAMP-CABIN.

The lamp-cabin provides accommodation for 2,000 Marsaut lamps, which belong to the company, and are cleaned, lighted, locked with lead-locks, and tested by gas before delivery to the workmen. The cleaning is almost entirely done by machinery. The number of hands required to

take in, clean, and serve out the 2,000 lamps is eighteen men and boys, and one man and two boys for repairs. The motive power is supplied by a 2 horse-power gas engine.

PUMPING ENGINE.

A Cornish engine with a cylinder 5 feet in diameter and 7 feet stroke, works seven pumps varying from 6 to 15 inches in diameter.

FITTING SHOPS, ETC.

The fitting shops are supplied with the necessary lathes and tools requisite for colliery work. In the smith's shop are two steam hammers, one for light, and the other for heavy work ; the former is novel in structure and most useful.

MEMOIRS OF DECEASED MEMBERS.

EDMUND BROMLEY was born on March 22nd, 1808, at Pentrich, Derbyshire. He served an apprenticeship with the Butterley Company, and was successively employed by the following firms of machine makers :—Messrs. Busk, Keen & Co., London ; Messrs. Clarke & Sons, Manchester ; and Messrs. Cochrane & Higgins, Salford. In 1847 he was engaged by Messrs. Alfred & Edmund Barnes at the Grassmoor collieries, and remained there as chief engineer for the succeeding 41 years, during which the collieries developed into a concern of the first magnitude.

He was an original promoter of the Chesterfield and Derbyshire Institute of Engineers, and became its treasurer in 1871, and so continued for eighteen years, until increasing infirmities caused his retirement from that office, when he was made an honorary member.

He contributed the first paper published by the Institute "On Carrett, Marshall & Co.'s Hydraulic Pumping Engine, Draining Dip Workings at Grassmoor Colliery ; with introductory Notices of other Hydraulic Engines." He subsequently contributed a paper "On Rainfall," containing the result of his own daily observations together with more general matter. He was a most regular attendant at the Council as well as the General Meetings, and for several years a Vice-President.

On May 30th, 1888, he was seized with paralysis, and although he partly regained the use of his limbs, his brain never recovered from the shock. He, however, survived for four years, and died at Norton, near Sheffield, on May 13th, 1892, his remains being brought, for interment, to Hasland churchyard.

FRANCIS HOLT was born at Todmorden, in Yorkshire, on December 5th, 1825. He served his apprenticeship with Messrs. Sharp, Stewart & Co., of Manchester, and remained with them for some time as foreman. He was afterwards employed at Woolwich dockyard ; and in Italy in connexion with the construction of a railway at Pisa. In consequence of the stoppage of the latter undertaking through financial difficulties, he returned to England and assumed, for a year and a half, the charge of the locomotive department of the South Staffordshire railway at Walsall. Relinquishing this appointment he went out to India to erect a cotton-mill for the Oriental Spinning and Weaving Company, at Bombay, where he remained for three years. He next accepted the position of manager at Messrs. Beyer, Peacock & Co's. locomotive works, at Gorton, near Manchester, which he held for some years, and was afterwards engaged as manager by Messrs. Hawthorn & Co., at Newcastle-upon-Tyne.

In 1874, he undertook the management of the Midland Railway Co.'s locomotive works, at Derby, where he remained up to the time of his death. During his connexion with these works, important extensions took place, in which Mr. Holt bore a conspicuous part. He was well known in the railway and engineering world as a man of large and varied experience, and for indomitable perseverance in whatever he undertook. He was the inventor of an arrangement for water, steam, and air-pipe connexions between locomotive engines and tenders, also for securing and finishing the eccentrics on crank-shafts, and he, along with Mr. Gresham of Manchester, invented an arrangement for applying sand or other substances to prevent the slipping of the driving wheels of locomotives.

He became a member of the Chesterfield and Derbyshire Institute of Engineers on July 14th, 1879, the date of the opening of the Stephenson Memorial Hall, and was for several years a member of the Council, serving on committees and taking an active interest in its proceedings. He died at Spondon, near Derby, on January 7th, 1893, and was interred at Spondon cemetery.

FREDERICK SAMUEL MARSH was born in 1857 at Nottingham, and was the second son of Mr. Samuel Marsh, manager of the Clifton collieries of that town. He was a pupil with Mr. George Fowler, and, after the usual course of training, became resident manager for Messrs. Morris and Shaw, at the Birch Coppice collieries, near Tamworth, which post he held until his death. He encountered the usual difficulties which trouble a colliery manager with a very fair share of success. He became a member of the Chesterfield and Derbyshire Institute of Engin-

eers on October 8th, 1881. He contributed a paper on "Germans," and another, entitled "One Use for the Telephone." In February, 1883, he was presented with the Albert bronze medal for his assistance in the work of rescuing life at the Baddesley colliery after an explosion, which occurred May 2nd, 1882. His discharge of difficult duties and great conscientiousness endeared him to all those people amongst whom his life was spent, and there was a striking manifestation at the time of his death of the strong affection and respect with which he was regarded by those connected with the Birch Coppice collieries. An attack of pneumonia cut short a career which the quiet observance of duty made honourable and useful, on July 25th, 1892, at the comparatively early age of 35.

ALFRED WOODIWISS, the second son of Sir Abraham Woodiwiss, was born in 1855, and received his education at Ockbrook, near Derby. He was exceedingly popular on account of his numerous good qualities, which endeared him to a large number of friends, but, being of a retiring disposition, he repeatedly declined invitations to take part in local public offices. He was, however, an able and clever man of business, and many years ago was employed by his father in a responsible position in connexion with some of the great railway enterprises with which the late Sir Abraham Woodiwiss was identified. He was a considerable traveller and had made a voyage round the world. He and his father, the latter being then mayor of Derby, joined the Chesterfield and Derbyshire Institute of Engineers on August 13th, 1881.

He fell a victim to typhus fever and pneumonia, his death, at the age of 37 years, taking place at his residence, Belair, Birkdale, on November 13th, 1892.

MIDLAND INSTITUTE OF MINING, CIVIL, AND
MECHANICAL ENGINEERS.

ANNUAL GENERAL MEETING,
HELD AT BARNSELEY, JULY 26TH, 1893.

MR. W. E. GARFORTH, PRESIDENT, IN THE CHAIR.

The minutes of the last meeting were read and confirmed.

The following gentlemen were elected Members, having been previously nominated :—

MR. FRANCIS ERNEST CHAMBERS, Mining Student, Tinsley Colliery, Sheffield.
MR. JOHN JAMES PATTISON, Colliery Manager, Morley West End Colliery,
Batley.
MR. WM. SETTLE, Mining Engineer, Darcy Lever, Bolton.
MR. JOHN SMITH, Mining Engineer, Bickershaw Collieries, Leigh.
MR. W. WILDE, Colliery Manager, Darfield Main Colliery, Barnsley.
MR. GUY WOOD, Commercial Manager, Darfield Main Colliery, Barnsley.

Mr. W. A. Ritson and Mr. R. Turnbull were appointed scrutineers of the voting papers for the election of officers for the year 1893-94, and of the balloting lists for representatives on the Council of the Federated Institution of Engineers for the year 1893-94.

The SECRETARY (Mr. T. W. H. Mitchell) read the Annual Report of the Council as follows :—

THE COUNCIL'S ANNUAL REPORT.

The Council have pleasure in handing the members of the Institute their report on the work of the past year.

The number of members on the books of the Institute at the end of the year was 3 Life Members, 18 Honorary Members, and 190 Ordinary Members. This is an increase of 18 in the number of Ordinary Members.

The arrears of subscriptions during the past year are £21 18s., all of which the Council consider good and hope that the amount will be paid during the current year.

From the statement of accounts which have been duly audited, it will be seen that there is a balance in hand of £26 2s. 7d., after paying all liabilities against the Institute. This must be considered very satisfactory when it is remembered that the Institute has been unexpectedly called upon by the Federated Institution of Mining Engineers to contribute the sum of £25 1s. to meet the deficiency on the first three years' working of that Institution.

A very successful joint meeting with the Chesterfield Institution was held at Sheffield in April, when papers were read on a "Combined Centre-line Apparatus," by Mr. W. Foulstone, and a description of the "Arrangements for Sinking to the Whinmoor Seam from the Silkstone Seam at the Tankersley Collieries," by Mr. W. Hoole Chambers.

Through the kindness of the proprietors and managers of the Cadeby and Rotherham Main Collieries the members of the two institutes had an opportunity of visiting those important collieries.

The Council take the opportunity of thanking the owners and managers of collieries for their kindness in allowing inspections of their mines and works, and consider that the benefits which are derived therefrom are of great value not only to the older members of the Institute, but of exceptional value to the junior members, as they have the advantage of seeing more modern appliances put down for the working of collieries, and as the mines get deeper (as they are doing in this district), each new winning affords experience for any future sinkings. This experience will enable the mining profession to cope with the difficulties which will, no doubt, be entailed in reaching and working seams of coal at great depths.

The Council hope that members who have special appliances, for dealing with special difficulties met with in working their collieries, will afford the members of the Institute an opportunity of viewing the same.

The Council desire to call the attention of the members to the increase in the number of institutes joining the Federated Institution of Mining Engineers. On August 1st, the Mining Institute of Scotland will become federated, and as the next meeting of the Federated Institution will be held in Glasgow in September, the Council think it would be a fitting opportunity for the members of this Institute to welcome the Mining Institute of Scotland.

The following papers have been read during the past year:—

“Underground Haulage at the West Riding Collieries, Normanton,” by Mr. W. E. Garforth.

“Endless Rope Haulage at the Thorncliffe, Rockingham, and Tankersley Collieries,” by Mr. W. Hoole Chambers.

Inaugural Address by the President, Mr. W. E. Garforth.

“The Wear and Tear of Steam Boilers due to Expansion and Contraction Strains,” by Mr. J. Clarke Jefferson.

“Some Systems of Underground Haulage at Messrs. Charlesworth’s Collieries,” by Mr. Walter Hargreaves.

“Experiments upon two Fans, at St. John’s Colliery, Normanton,” by Mr. E. Brown.

The Council would call the attention of the members to the paragraph in the President’s address giving subjects for various papers, viz., different methods for working coal, including the more extended use of coal-cutting machines; the systems of ventilation, dealing with increased temperature; the more economical use of compressed-air; the applications of electricity; the best means of conveying coal underground; the different systems of washing small coal; the use of explosives in those mines where longwall cannot properly be worked; coal-dust; safety-lamps; and means for detecting fire-damp; and trust that the members will make an effort to bring any of the above-named subjects before the Institute in the shape of papers so that this Institute may, as regards the contribution of papers, maintain its position in the *Transactions* of the Federated Institution of Mining Engineers.

Mr. LUPTON said the increase of members was very satisfactory and the list of papers showed that the Institute was more vigorous than ever.

The report was then adopted unanimously.

ACCOUNTS.

Mr. H. B. NASH (one of the auditors) read the statement of accounts for the year ending June 30th, 1893, as follows:—

MIDLAND INSTITUTE OF MINING, CIVIL, AND MECHANICAL ENGINEERS.
GENERAL STATEMENT, 1892-93.

LIABILITIES.		ASSETS.	
1893.	£ s. d.	1893.	£ s. d.
June 30.—None		June 30.—By Cash in Bank ...	23 7 8
Balance, being capital ...	... 402 10 7	" " Treasurer's hands ...	2 14 11
		" " Estimated Value of Instruments for Fan Experiments	
		" " Value of Transactions, 6,756	
		" " parts at 1s. each ...	837 16 0
		" " 18 Copies of French Commission Report on the Use of Explosives, at 3s. each	2 14 0
		" " Arrears of Subscriptions ...	... ..
			340 10 0
			21 18 0
			£402 10 7
Audited and found correct,		H. B. NASH, } Auditors. E. W. THIRKELL,	

ACCOUNTS.

Mr. NASH said the general statement showed they had no liabilities whatever, which was most satisfactory. He moved that the accounts and balance-sheet be passed.

Mr. J. NEVIN seconded the motion, saying the accounts were most satisfactory, and that it was a treat to have no liabilities.

The PRESIDENT said the Transactions were only valued at 1s. per copy. He thought they might realize more than that in the future.

The motion was carried unanimously.

The SECRETARY said there was nothing in the capital account for the value of the library.

Mr. NASH said there was nothing credited in the accounts, except the loose transactions in stock.

The PRESIDENT said he thought it would be better if everything was included. It was advisable to have a complete inventory.

Mr. NEVIN said they should state in the assets—library, so many volumes, and charge nothing for it.

Mr. LUPTON asked why not value the library at a fair price, keep it as an ordinary stock account, and depreciate it in the usual way?

Mr. NEVIN said the exchanges received every year would make up for any depreciation.

The PRESIDENT suggested that an inventory should be made.

Mr. NASH suggested that the books might be bound.

The SECRETARY promised to prepare a catalogue of the books to be presented to the next General Meeting.

CLASSIFICATION OF MEMBERS.

Mr. NEVIN said the Council had received a requisition from the Council of the Federated Institution of Mining Engineers, in accordance with their Bye-law 8 for the classification of members, and to meet this he moved "That the members of this Institute on the register on the 30th June, 1893, shall be classified as members under part B, sec. (a), and that all nominations in future must state the class to which members wish to belong, the Council reserving to themselves the right to recommend to a General Meeting the alteration of such classification should they think necessary."

The SECRETARY said it had been arranged that all present members should be placed in class (a).

The PRESIDENT said the members knew that when the Institute was in an impoverished state they welcomed commercial members to help them to pay the cost of printing the *Transactions*. The Council had had the matter under consideration for some time, and found a difficulty in classifying certain members. Some members connected with trade had no objection to be put down as commercial men, but there were others, especially gentlemen, who took part in the commercial management of a colliery, but had nothing to do with the underground department who objected to be placed in class (b.) The Council thought it would be better in future elections to classify them, but to let the old members remain as at present.

Mr. A. LUPTON—All existing members remain in perpetuity in class (a), and the division will apply only to new members?

The PRESIDENT said that was so. It was expected in the next year or two probably some further rule would be made, and that would be the time to further divide the members. For the present they thought it would be better to make no distinction as regards old members.

Mr. THIRKELL seconded the resolution, saying the matter had been carefully thought out, and he was quite in favour of it.

Mr. LUPTON said it seemed to him a most important resolution.

Mr. NEVIN said alterations of rules could only be made at the Annual General Meeting.

The PRESIDENT agreed that it was an important question. The matter was under discussion at the Council Meeting of the Federated Institution of Mining Engineers, in June, and the representatives of every institute expressed their difficulty in conforming to this rule. The representatives of the North of England Institute of Mining Engineers advised that the present members be left under one head, and from a certain date, which might be from that day, to classify the new members as proposed. The idea was to place the mining and mechanical engineer and colliery manager respectively in their proper positions.

Mr. NASH said he supposed it was intended to work themselves gradually on the same lines as the Institution of Civil Engineers, so that when they got a charter of Incorporation they should be in a position to put themselves in line with as little detail work as possible.

Mr. LUPTON said he did not oppose the resolution which did not prejudice any existing member. At the same time it would be a good thing if it were understood that in future notice should be given to members of important resolutions.

The SECRETARY pointed out that this did not in any way interfere

with or alter the rules of the Institute, that in the present nomination forms there was a blank left for the proposers to state to what class the member wished to belong and that this was a matter that could be left to the Council.

Mr. THIRKELL said that members knew that business was done at the Annual General Meetings which could not be done at other meetings.

The resolution was then adopted unanimously.

ELECTION OF OFFICERS.

The Scrutineers reported the result of the election of officers for the year 1893-94 as follows:—

PRESIDENT.

W. E. GARFORTH, Esq.

VICE-PRESIDENTS.

W. HARGREAVES, Esq., J. LONGBOTHAM, Esq., H. B. NASH, Esq.

COUNCIL.

J. E. CHAMBERS, Esq.
W. HOOLE CHAMBERS, Esq.
H. S. CHILDE, Esq.
S. H. HEDLEY, Esq.

T. R. MADDISON, Esq.
J. NEVIN, Esq.
E. W. THIRKELL, Esq.
G. B. WALKER, Esq.

SECRETARY AND TREASURER.

T. W. H. MITCHELL, Esq.

Mr. W. HOOLE CHAMBERS moved a hearty vote of thanks to the President for his conduct in the chair during the past year. Mr. Garforth had thrown into the business of the Institute an amount of work which had been greatly appreciated by the members, and had reflected great credit upon himself. It was not desirable for him to make invidious distinctions, but he was sure the conduct of the President in the past year had been such as would raise the character of the Institute and do them credit amongst the other institutes. He trusted that next year the President would receive greater help in the way of papers and discussions, which would enhance the interests of the Institute and the honour of this important district.

Mr. LUPTON had great pleasure in seconding the motion. He had the privilege of knowing Mr. Garforth more than twenty years ago, and whatever the situation he was in his mind was working upon the business in hand, and making suggestions for the benefit of the business he was doing.

The resolution was carried unanimously.

The PRESIDENT said he was extremely obliged for the kind manner in which they had spoken of the work he had tried to do during the past year. He could not have dispensed with the assistance and hearty support of the Vice-Presidents, Council, and members. He thanked them for appreciating what he had done, and hoped to go on satisfactorily during the present year.

REPRESENTATIVES ON THE COUNCIL OF THE FEDERATED INSTITUTION OF MINING ENGINEERS FOR THE YEAR 1893-94.

The Secretary reported the result of the ballot as follows :—

W. E. GARFORTH, Esq.	|	JOS. MITCHELL, Esq.
J. LONGBOTHAM, Esq.	|	C. E. RHODES, Esq.
J. NEVIN, Esq.		

MINERS' SAFETY-LAMPS.

Mr. BEST exhibited and explained an arrangement for lighting and re-lighting safety-lamps by electricity.

The PRESIDENT asked how many lamps one man could light in one morning?

Mr. BEST said the apparatus he had shown was only intended for lighting lamps at a lamp-station in the workings. For lighting lamps in the lamp-room the wire was taken to the window, and when a man asked for his lamp it was lighted as it was handed out to him. About 500 lamps could be lighted in a morning between 5.30 and 6 a.m. One lamp could be put out and re-lighted six times in 10 seconds. The system, however, was not yet in use at any colliery.

Mr. NASH said they lit the lamps by electricity at the Hemsworth Fitzwilliam colliery as the men applied for them.

Mr. THIRKELL asked if a current was not supplied to the lamp-cabin to light several lamps at once?

Mr. BEST said the idea was that no more lamps should be lighted than were wanted. If there were four windows at the light-cabin, the dynamo should be sufficiently strong to light four lamps at once.

The PRESIDENT said lamps had been lighted by an incandescent platinum wire, which he had seen in use at the West Riding colliery and at Bolsover colliery.

Mr. LUPTON said he showed an electric lighting apparatus some years ago at one of his lectures at the Yorkshire college. The light was obtained by means of platinum wires and a continuous current. Some years were spent in improving the apparatus, and he understood it was now being introduced largely at collieries. That apparatus would light any kind of oil in a lamp. There were many advantages in the use of electricity, beyond the economy of time and oil. He liked Mr. Best's apparatus as it used a dynamo instead of a battery. When a secondary battery was used for the purpose, there was electric force always present in the battery, and many ingenious devices had to be used to prevent sparking when the lamp was connected to the battery. In the Best apparatus there was no electric force until the lamp had been attached and the handle turned, which was an element in favour of the dynamo as against the primary or secondary battery when used for relighting lamps in the mine.

The PRESIDENT asked Mr. Thirkell if he could give information as to the life of the different parts of a lamp?

Mr. THIRKELL said he should be pleased to do so at the next meeting.

Mr. NEVIN proposed a vote of thanks to Mr. Best. If safety-lamps could be lighted one at a time at the window as they were given out, instead of being lighted an hour and a half before they were given out, it would be a great gain. Whether the Chapman and Graham apparatus was better than the platinum-wire process was a question which would have to be decided by results.

Mr. NASH seconded the motion. There was no doubt that lighting lamps by electricity on some safe method would be most useful. The saving of time and labour would be considerable by the use of an apparatus for lighting lamps one or two miles in-by, and with safety. Many men would be kept at work who otherwise would have lost many hours of valuable time.

The resolution was carried, and was briefly acknowledged by Mr. Best.

The annual dinner was afterwards held at the King's Head Hotel.

APPENDICES.

I.—BAROMETER, THERMOMETER, ETC., READINGS FOR
THE YEAR 1892.

BY M. WALTON BROWN.

The barometer, thermometer, etc., readings have been supplied by permission of the authorities of the Glasgow and Kew Observatories, and give some idea of the variations of temperature and of atmospheric pressure in the intervening districts in which the mining operations of this country are chiefly carried on.

The barometer at Kew is 34 feet, and at Glasgow is 180 feet, above sea-level. The barometer readings at Glasgow have been reduced to 32 feet above sea-level, by the addition of 0·150 inch to each reading, and the barometer readings at both observatories are reduced to 32 degs. Fahr.

The fatal explosions in collieries are obtained from the annual reports of H.M. Inspectors of Mines, and are printed upon the diagrams (Plates XVII., XVIII., XIX., and XX.) recording the meteorological observations.

JANUARY, 1892.

KEW.								GLASGOW.							
BAROMETER.					TEMPERATURE.		Direction of wind at noon	BAROMETER.					TEMPERATURE.		Direction of wind at noon
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.		Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.	
1	29.736	29.844	29.940	30.063	43.2	35.7	W	1	29.593	29.783	29.948	30.032	41.2	35.9	WNW
2	30.184	30.236	30.157	30.104	41.8	31.8	WSW	2	29.958	29.910	29.799	29.736	44.0	38.4	W
3	30.027	30.030	30.015	30.019	43.5	31.9	NW	3	29.822	29.867	29.872	29.953	38.1	31.6	WNW
4	30.016	30.054	30.057	30.112	35.1	27.0	NW	4	30.002	30.074	30.050	29.946	36.1	29.0	NW
5	30.063	29.954	29.690	29.541	42.5	24.9	SW	5	29.617	29.430	29.379	29.311	43.6	35.0	WNW
6	29.490	29.357	29.399	29.450	44.2	32.8	NW	6	29.206	29.170	29.220	29.300	37.3	28.7	NW
7	29.432	29.401	29.323	29.273	37.0	30.5	SW	7	29.280	29.202	29.167	29.251	34.1	24.0	SSW
8	29.306	29.447	29.437	29.401	34.7	28.4	W	8	29.251	29.233	29.323	29.459	34.3	29.7	W
9	29.364	29.435	29.428	29.423	32.7	24.9	NNW	9	29.496	29.537	29.502	29.532	33.9	25.9	N
10	29.436	29.533	29.581	29.673	32.1	24.1	N	10	29.558	29.746	29.889	30.000	36.0	29.4	NE
11	29.761	29.817	29.851	29.912	35.8	29.8	N	11	30.034	30.013	29.917	29.845	36.0	27.2	SW
12	29.895	29.916	29.823	29.814	35.4	24.3	N	12	29.770	29.825	29.867	29.871	37.8	29.6	E
13	29.781	29.751	29.630	29.573	36.8	30.7	NE	13	29.789	29.643	29.446	29.370	35.3	27.9	NE
14	29.491	29.480	29.439	29.460	34.5	28.9	N	14	29.300	29.268	29.293	29.325	36.3	33.2	S
15	29.464	29.491	29.475	29.490	34.3	25.2	NW	15	29.386	29.411	29.396	29.357	33.9	26.3	E
16	29.457	29.488	29.473	29.494	36.3	23.8	SE	16	29.350	29.368	29.379	29.471	32.1	24.8	E
17	29.493	29.565	29.573	29.608	37.5	32.7	E	17	29.550	29.593	29.608	29.636	37.8	30.8	ESE
18	29.640	29.734	29.770	29.833	44.0	36.8	E	18	29.651	29.687	29.702	29.727	37.8	35.5	ENE
19	29.831	29.847	29.827	29.843	41.2	32.8	E	19	29.745	29.825	29.842	29.817	38.0	33.9	NE
20	29.833	29.850	29.863	29.931	37.7	32.4	E	20	29.780	29.810	29.861	29.894	35.2	33.9	E
21	29.963	29.947	29.892	29.877	36.4	30.4	E	21	29.839	29.730	29.512	29.478	40.0	34.1	SSW
22	29.886	29.845	29.827	29.915	45.7	34.9	S	22	29.575	29.610	29.616	29.679	39.9	34.6	SSW
23	29.906	29.963	29.932	29.972	49.3	41.4	SW	23	29.760	29.761	29.615	29.623	45.3	38.9	S
24	29.977	30.092	30.180	30.256	49.3	33.9	NW	24	29.726	29.883	29.985	30.061	43.5	37.2	W
25	30.317	30.418	30.448	30.477	42.3	31.8	NW	25	30.155	30.280	30.316	30.322	43.2	35.5	WSW
26	30.493	30.474	30.358	30.274	43.5	29.8	SW	26	30.205	30.119	30.064	29.951	46.8	40.2	SW
27	30.180	30.092	29.847	29.878	47.2	41.6	SW	27	29.770	29.547	29.537	29.746	47.8	35.9	SW
28	30.111	30.277	30.244	30.171	47.8	36.7	WSW	28	29.883	29.820	29.741	29.659	48.5	35.8	SW
29	30.057	30.085	30.149	30.197	51.9	47.8	W	29	29.635	29.672	29.799	29.765	51.2	48.4	SW
30	30.175	30.179	30.106	30.066	50.8	46.8	W	30	29.768	29.800	29.778	29.820	48.4	40.3	SW
31	30.050	30.134	30.103	29.987	49.8	45.6	N	31	29.847	29.919	29.816	29.470	46.6	39.4	SW

FEBRUARY, 1892.

1	29.766	29.537	29.416	29.383	48.0	37.5	SW	1	29.107	28.862	28.801	28.846	46.6	34.9	SW	
2	29.226	29.328	29.223	29.153	42.4	33.7	W	2	28.858	28.789	28.617	28.914	40.7	29.9	WSW	
3	29.143	29.264	29.402	29.614	43.5	35.8	WNW	3	29.082	29.272	29.426	29.556	40.0	32.7	WNW	
4	29.722	29.733	29.587	29.525	45.3	31.0	SSW	4	29.537	29.356	29.155	29.246	41.6	31.6	SSW	
5	29.546	29.608	29.708	29.814	48.3	38.5	W	5	29.199	29.323	29.418	29.477	41.1	34.7	W	
6	29.829	29.860	29.828	29.869	45.5	38.7	W	6	29.521	29.603	29.635	29.719	43.4	37.7	WSW	
7	29.901	29.924	29.828	29.774	52.9	43.8	SW	7	29.712	29.568	29.393	29.528	48.4	40.0	W	
8	29.797	29.683	29.778	30.037	50.5	44.5	NW	8	29.522	29.691	29.896	30.013	48.2	40.3	WNW	
9	30.214	30.312	30.300	30.300	47.7	41.4	SSW	9	30.116	30.138	30.139	30.175	48.3	40.2	SW	
10	30.278	30.321	30.325	30.383	49.2	44.0	NW	10	30.185	30.221	30.222	30.281	47.9	43.6	WSW	
11	30.401	30.439	30.433	30.430	50.0	38.1	NW	11	30.295	30.342	30.368	30.390	49.3	44.3	W	
12	30.457	30.471	30.434	30.452	43.4	32.9	NNW	12	30.374	30.420	30.409	30.469	48.7	41.8	WSW	
13	30.453	30.503	30.472	30.462	42.3	34.2	N	13	30.524	30.564	30.491	30.400	44.1	38.8	NE	
14	30.366	30.214	29.918	29.717	41.0	32.3	SW	14	30.193	29.945	29.682	29.581	44.4	37.4	SW	
15	29.490	29.431	29.445	29.579	41.9	29.7	WNW	15	29.616	29.694	29.761	29.822	38.3	31.4	ENE	
16	29.595	29.614	29.602	29.576	30.8	23.7	NE	16	29.857	29.898	29.803	29.678	34.9	28.2	NE	
17	29.528	29.490	29.336	29.106	33.5	19.2	W	17	29.405	29.243	29.183	29.167	36.1	30.3	NE	
18	29.069	29.176	29.267	29.350	33.7	23.0	NW	18	29.243	29.275	29.280	29.368	33.1	29.4	W	
19	29.337	29.319	29.266	29.182	34.0	23.5	E	19	29.394	29.412	29.409	29.460	33.4	14.8	ESE	
20	29.191	29.351	29.423	29.423	37.0	28.8	NE	20	29.473	29.474	29.497	29.554	33.5	24.0	NE	
21	29.341	29.411	29.438	29.461	46.8	36.1	S	21	29.491	29.419	29.365	29.432	36.2	31.1	ENE	
22	29.452	29.543	29.578	29.642	50.5	38.2	S	22	29.431	29.446	29.445	29.520	39.8	33.3	NE	
23	29.651	29.646	29.656	29.735	48.8	36.1	SE	23	29.562	29.620	29.645	29.678	45.0	35.2	E	
24	29.756	29.778	29.780	29.848	48.0	34.7	NE	24	29.681	29.730	29.718	29.757	42.7	35.2	ENE	
25	29.854	29.883	29.880	29.941	52.2	37.1	E	25	29.774	29.820	29.827	29.882	40.2	38.0	E	
26	29.953	30.049	30.067	30.106	42.1	36.2	ENE	26	29.927	30.009	30.025	30.094	42.9	35.5	ENE	
27	30.086	30.108	30.038	29.994	40.9	34.3	NE	27	30.117	30.130	30.101	30.090	39.2	35.9	ENE	
28	29.939	29.890	29.830	29.833	41.9	41.4	NE	28	30.038	30.019	29.946	29.962	44.1	34.3	E	
29	29.804	29.831	29.831	29.863	34.9	35.3	N	29	29.966	30.000	30.019	30.071	40.3	34.5	NE	

MARCH, 1892.

KEW.										GLASGOW.											
BAROMETER.								TEMPERATURE.		Direction of wind at noon	BAROMETER.								TEMPERATURE.		Direction of wind at noon
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.			Date.		4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.					
1	29.826	29.883	29.888	29.866	39.9	33.5		NNE		1	30.080	30.127	30.136	30.212	40.0	34.7		NE			NE
2	29.954	30.050	30.091	30.148	34.0	28.2		NE		2	30.240	30.294	30.304	30.344	35.2	32.9		ENE			ENE
3	30.177	30.234	30.219	30.243	31.8	28.1		NE		3	30.348	30.365	30.312	30.360	34.1	31.8		ESE			ESE
4	30.241	30.284	30.298	30.332	32.9	29.1		NE		4	30.357	30.387	30.342	30.356	38.2	29.4		N			N
5	30.314	30.303	30.238	30.230	30.4	26.7		N		5	30.339	30.325	30.257	30.250	36.1	28.5		NE			NE
6	30.199	30.201	30.085	30.036	35.8	31.1		E		6	30.199	30.168	30.103	30.078	38.8	31.2		E			E
7	29.964	29.958	29.896	29.901	36.6	29.3		E		7	30.005	29.977	29.906	29.901	38.2	31.8		S			S
8	29.888	29.906	29.855	29.865	34.5	25.8		NNE		8	29.845	29.819	29.699	29.588	41.5	31.1		WSW			WSW
9	29.754	29.557	29.462	29.476	38.9	22.2		WSW		9	29.439	29.407	29.355	29.166	33.1	25.4		WNW			WNW
10	29.423	29.313	29.278	29.395	36.4	24.6		WSW		10	29.193	29.401	29.528	29.648	38.0	27.5		NW			NW
11	29.502	29.565	29.580	29.607	38.1	26.9		N		11	29.630	29.650	29.656	29.686	39.5	30.0		ENE			ENE
12	29.572	29.533	29.434	29.366	37.7	27.2		NNW		12	29.648	29.591	29.467	29.463	38.2	29.5		N			N
13	29.350	29.348	29.327	29.368	40.5	24.9		W		13	29.355	29.353	29.352	29.338	38.9	30.5		NE			NE
14	29.377	29.464	29.510	29.656	39.1	25.8		W		14	29.320	29.361	29.388	29.420	39.2	28.9		WSW			WSW
15	29.674	29.599	29.273	29.299	43.8	31.5		S		15	29.406	29.320	29.260	29.423	38.8	27.5		SE			SE
16	29.619	29.898	29.968	30.032	51.5	37.3		W		16	29.611	29.708	29.671	29.654	44.4	26.7		S			S
17	30.063	30.141	30.186	30.265	56.0	45.3		SW		17	29.631	29.609	29.500	29.918	50.3	43.9		SSW			SSW
18	30.290	30.316	30.241	30.244	59.2	40.8		SE		18	29.998	30.101	30.114	30.138	57.7	47.2		SSE			SSE
19	30.218	30.208	30.144	30.150	52.3	38.0		ENE		19	30.154	30.210	30.186	30.255	58.8	39.9		SE			SE
20	30.122	30.123	30.141	30.233	48.2	32.1		E		20	30.238	30.232	30.153	30.214	46.4	34.5		NE			NE
21	30.273	30.343	30.284	30.332	51.6	27.5		E		21	30.232	30.293	30.297	30.405	46.2	31.2		N			N
22	30.328	30.387	30.407	30.483	41.7	37.7		NE		22	30.486	30.573	30.558	30.570	48.1	35.2		N			N
23	30.482	30.478	30.370	30.364	47.2	34.1		NE		23	30.501	30.464	30.373	30.343	53.3	39.2		WNW			WNW
24	30.310	30.295	30.218	30.172	44.2	36.7		NE		24	30.253	30.204	30.131	30.071	48.9	37.7		W			W
25	30.099	30.036	29.864	29.792	49.8	38.0		SE		25	29.959	29.883	29.745	29.633	44.7	40.0		WSW			WSW
26	29.685	29.669	29.613	29.635	57.0	37.6		W		26	29.543	29.531	29.610	29.743	43.6	28.0		SW			SW
27	29.643	29.710	29.720	29.781	49.6	38.9		W		27	29.823	29.911	29.936	29.988	35.1	26.2		NE			NE
28	29.820	29.908	29.996	30.140	39.0	32.0		N		28	29.962	29.958	30.044	30.266	40.0	24.2		WSW			WSW
29	30.256	30.416	30.457	30.539	40.0	31.2		N		29	30.377	30.464	30.472	30.498	41.2	23.3		S			S
30	30.528	30.551	30.483	30.543	49.3	32.6		NE		30	30.504	30.523	30.491	30.494	47.8	32.8		SSW			SSW
31	30.518	30.550	30.495	30.482	53.8	32.9		NE		31	30.456	30.446	30.399	30.399	55.1	35.6		SSW			SSW

APRIL, 1892.

1	30.466	30.455	30.362	30.391	65.0	30.0	N	1	30.394	30.415	30.377	30.385	60.8	39.1	W
2	30.386	30.370	30.302	30.310	62.3	35.9	E	2	30.360	30.355	30.293	30.291	63.7	33.7	NE
3	30.258	30.237	30.102	30.084	64.1	34.5	ENE	3	30.249	30.209	30.074	30.023	61.1	37.5	SSE
4	29.966	29.967	29.933	29.983	68.5	37.0	W	4	29.904	29.840	29.796	29.839	59.5	39.8	S
5	29.965	29.974	29.866	29.926	68.7	38.0	SSW	5	29.835	29.879	29.889	29.932	50.7	44.1	SSE
6	29.921	29.926	29.873	29.911	65.0	43.2	E	6	29.935	29.977	29.967	30.002	52.7	44.5	NE
7	29.893	29.907	29.859	29.927	64.3	42.6	NE	7	29.992	30.017	30.000	30.053	49.0	41.0	ENE
8	29.916	29.946	29.891	29.939	63.9	39.8	NE	8	30.060	30.068	30.026	30.065	53.8	40.0	E
9	29.923	29.934	29.895	29.925	59.8	41.9	NE	9	30.098	30.108	30.032	30.062	51.7	39.0	ENE
10	29.918	29.934	29.907	29.942	63.5	39.9	ENE	10	30.048	30.048	29.965	29.996	57.2	37.0	ENE
11	29.921	29.914	29.845	29.901	63.2	34.9	NNE	11	29.971	29.966	29.935	30.022	50.0	29.4	NE
12	29.864	29.865	29.822	29.771	43.2	33.9	NNE	12	29.994	29.983	29.883	29.844	43.0	35.4	E
13	29.656	29.642	29.606	29.643	39.7	34.0	NE	13	29.807	29.764	29.685	29.708	42.2	29.4	N
14	29.644	29.682	29.671	29.714	45.3	30.0	N	14	29.680	29.679	29.647	29.684	42.3	27.2	SE
15	29.704	29.743	29.667	29.610	48.0	27.9	W	15	29.688	29.703	29.674	29.679	39.5	25.9	SW
16	29.471	29.490	29.542	29.625	45.6	33.2	NNW	16	29.629	29.629	29.631	29.700	40.5	26.3	NE
17	29.648	29.700	29.728	29.864	46.8	29.8	N	17	29.717	29.745	29.747	29.853	46.7	25.4	W
18	29.926	30.023	30.048	30.179	48.1	31.3	NW	18	29.893	29.966	30.024	30.173	47.9	29.3	NW
19	30.271	30.360	30.356	30.402	50.8	31.3	WNW	19	30.221	30.240	30.174	30.096	49.8	27.7	SW
20	30.386	30.350	30.346	30.143	48.8	38.3	SW	20	30.065	30.078	29.926	29.822	56.1	42.5	SW
21	30.059	30.117	30.146	30.213	62.1	47.9	NW	21	29.863	29.922	29.874	29.845	51.9	43.9	SW
22	30.219	30.253	30.256	30.347	65.8	48.2	W	22	29.886	30.008	30.094	30.158	53.9	42.7	WSW
23	30.380	30.414	30.335	30.327	63.5	40.8	W	23	30.173	30.198	30.175	30.159	53.1	42.9	WSW
24	30.277	30.328	30.238	30.133	60.0	48.7	NNW	24	30.174	30.177	30.077	29.931	52.1	40.4	W
25	29.959	29.842	29.819	29.884	55.0	41.5	NW	25	29.808	29.785	29.761	29.784	51.0	37.4	NNW
26	29.863	29.846	29.814	29.863	54.3	36.8	NW	26	29.795	29.821	29.739	29.772	52.1	34.4	NNW
27	29.835	29.785	29.613	29.578	55.0	33.1	SW	27	29.600	29.388	29.357	29.580	48.3	36.3	NW
28	29.534	29.601	29.778	29.913	41.7	35.7	N	28	29.806	29.881	29.858	29.870	48.3	37.3	N
29	29.889	29.905	29.853	30.080	48.0	35.2	NNE	29	29.801	29.975	29.977	30.013	50.9	35.4	NNH
30	30.134	30.179	30.146	30.172	56.0	31.9	N	30	30.002	30.024	30.034	30.011	52.5	38.8	WSW

MAY, 1892.

KEW.										GLASGOW.									
BAROMETER.								TEMPERA- TURE.		Direction of wind at noon	BAROMETER.								Direction of wind at noon
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.					Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.		
1	30.122	30.040	29.897	29.856	57.4	33.9		S			1	29.933	29.879	29.798	29.824	54.8	38.8		SW
2	29.805	29.800	29.772	29.779	48.1	39.9		NE			2	29.872	29.924	29.931	30.038	59.9	34.8		ENE
3	29.717	29.672	29.605	29.631	45.7	42.3		N			3	30.022	29.968	29.909	29.978	54.2	39.9		NE
4	29.669	29.735	29.801	29.916	48.5	41.5		NE			4	29.976	29.994	29.989	30.034	54.9	36.8		ESE
5	29.920	29.943	29.938	30.021	47.7	38.5		N			5	29.999	29.998	29.993	30.125	57.7	38.0		E
6	30.064	30.126	30.160	30.243	50.1	35.3		N			6	30.161	30.191	30.149	30.121	55.9	32.1		W
7	30.240	30.202	30.117	30.133	60.7	31.2		SW			7	30.030	29.972	29.956	29.978	53.6	39.7		WSW
8	30.139	30.150	30.106	30.135	63.4	39.9		W			8	29.993	30.018	30.018	30.047	56.1	41.8		W
9	30.152	30.160	30.121	30.170	65.8	37.2		SE			9	30.063	30.092	30.094	30.121	62.9	43.7		SW
10	30.169	30.161	30.124	30.181	64.0	41.0		ENE			10	30.155	30.174	30.162	30.278	67.3	39.2		NE
11	30.193	30.225	30.221	30.332	67.4	41.7		NE			11	30.343	30.363	30.335	30.391	60.3	40.4		ENE
12	30.359	30.355	30.285	30.304	68.0	42.1		NNE			12	30.407	30.366	30.247	30.218	64.2	39.6		NE
13	30.257	30.232	30.134	30.107	69.2	41.7		NNW			13	30.110	30.050	29.973	29.897	56.2	50.9		WSW
14	30.041	30.023	29.977	30.036	64.3	46.0		W			14	29.752	29.831	29.831	29.805	57.9	46.8		W
15	29.910	29.973	29.862	29.829	57.5	43.2		SW			15	29.636	29.552	29.548	29.522	57.4	46.4		W
16	29.792	29.756	29.691	29.674	61.9	45.0		W			16	29.382	29.283	29.298	29.546	53.1	44.7		WSW
17	29.749	29.883	29.966	30.071	61.5	48.4		NW			17	29.679	29.837	29.877	29.935	58.4	42.7		W
18	30.090	30.087	30.018	29.998	61.5	45.8		SW			18	29.899	29.748	29.701	29.717	55.2	41.2		NNW
19	30.000	30.009	30.067	30.070	62.4	46.9		W			19	29.702	29.791	29.810	29.650	56.9	42.5		W
20	29.938	29.845	29.843	29.927	61.8	48.9		W			20	29.544	29.561	29.724	29.914	57.0	39.3		NNW
21	30.023	30.063	29.970	29.979	64.3	44.0		W			21	29.901	29.828	29.783	29.814	53.7	38.2		WSW
22	29.961	29.983	29.937	29.936	66.2	43.4		SSW			22	29.870	29.901	29.837	29.767	51.2	39.5		SE
23	29.910	29.886	29.886	29.916	69.7	46.7		SW			23	29.643	29.655	29.637	29.602	57.2	43.0		W
24	29.905	29.896	29.862	29.860	71.4	51.9		S			24	29.534	29.677	29.641	29.699	62.1	50.7		SSW
25	29.740	29.716	29.752	29.805	75.2	53.2		S			25	29.680	29.580	29.550	29.666	60.9	48.5		ESE
26	29.781	29.785	29.766	29.776	75.3	55.1		ENE			26	29.715	29.782	29.739	29.705	64.8	48.4		W
27	29.766	29.836	29.856	29.846	71.7	59.0		S			27	29.651	29.705	29.752	29.837	66.0	53.3		WSW
28	29.729	29.690	29.696	29.824	77.9	52.6		S			28	29.537	29.809	29.677	29.543	61.0	49.3		ENE
29	29.928	29.984	29.988	30.068	66.9	51.1		SSW			29	29.443	29.616	29.617	29.673	62.8	48.9		SSW
30	30.071	30.108	30.071	30.030	73.5	55.2		SW			30	29.714	29.763	29.778	29.832	65.7	49.2		SSW
31	.....	29.848	29.714	29.759	80.7	55.4		S			31	29.774	29.711	29.649	29.563	68.5	55.0		SW

JUNE, 1892.

1	29.792	29.811	29.847	29.864	67.3	52.5		SW			1	29.470	29.508	29.512	29.623	62.2	47.5		SW
2	29.744	29.688	29.698	29.759	65.9	54.0		SW			2	29.558	29.260	29.291	29.437	54.2	45.9		S
3	29.826	29.915	29.949	30.021	65.9	50.3		SW			3	29.463	29.559	29.636	29.723	53.3	45.4		WSW
4	30.056	30.060	29.987	29.907	63.9	46.3		SW			4	29.752	29.778	29.713	29.583	58.9	45.9		SW
5	29.728	29.727	29.769	29.969	65.2	51.9		W			5	29.462	29.598	29.741	29.687	60.5	48.9		W
6	30.077	30.160	30.194	30.286	71.2	49.1		N			6	30.015	30.111	30.167	30.253	65.0	47.3		W
7	30.316	30.356	30.324	30.357	67.8	49.3		E			7	30.273	30.303	30.299	30.315	68.1	55.2		NW
8	30.356	30.379	30.321	30.314	69.3	48.0		E			8	30.308	30.311	30.274	30.275	76.1	53.0		WSW
9	30.273	30.231	30.157	30.106	74.8	53.2		E			9	30.243	30.214	30.116	30.058	77.3	53.8		W
10	30.020	29.923	29.816	29.792	80.7	51.1		S			10	30.015	29.995	29.918	29.857	60.2	45.8		E
11	29.773	29.778	29.747	29.779	68.3	55.0		SW			11	29.820	29.816	29.862	29.890	51.0	43.3		ESE
12	29.843	29.867	29.877	29.909	55.2	45.7		ENE			12	29.863	29.826	29.890	30.015	55.0	42.7		NNW
13	29.978	30.058	30.087	30.146	57.9	41.8		NNE			13	30.079	30.127	30.115	30.162	56.2	39.0		N
14	30.125	30.092	30.043	30.062	54.2	40.9		NE			14	30.191	30.185	30.086	30.076	62.2	39.0		SE
15	30.032	30.010	29.960	29.958	61.6	38.2		N			15	30.020	29.965	29.906	29.841	61.1	41.9		W
16	29.926	29.902	29.867	29.905	61.1	46.2		W			16	29.783	29.836	29.803	29.852	55.2	42.9		NNE
17	29.931	29.950	29.933	29.914	60.0	45.1		NW			17	29.847	29.824	29.881	29.949	57.4	39.4		NW
18	29.946	29.964	29.919	29.900	59.7	42.8		NNW			18	29.902	29.884	29.828	29.838	58.3	45.9		NE
19	29.870	29.838	29.799	29.827	63.3	45.2		SW			19	29.806	29.782	29.730	29.682	56.1	43.0		W
20	29.818	29.810	29.792	29.834	61.6	45.0		SW			20	29.641	29.703	29.726	29.795	59.0	47.3		E
21	29.853	29.886	29.903	29.933	69.9	46.0		SW			21	29.766	29.831	29.792	29.611	65.9	42.0		NNE
22	29.860	29.881	29.789	29.750	71.5	46.0		WSW			22	29.780	29.775	29.724	29.706	61.2	50.0		NW
23	29.883	29.900	29.641	29.815	62.9	51.0		NW			23	29.636	29.628	29.624	29.732	64.1	50.0		NW
24	29.911	29.965	29.948	29.976	70.5	46.5		S			24	29.769	29.824	29.834	29.861	65.0	46.9		W
25	29.961	29.954	29.867	29.880	66.3	51.6		S			25	29.820	29.747	29.628	29.610	58.0	48.4		WSW
26	29.958	30.020	30.032	30.073	75.0	51.6		WSW			26	29.684	29.715	29.671	29.684	67.0	54.0		SW
27	30.080	30.110	30.086	30.113	76.9	59.8		S			27	29.684	29.771	29.848	29.932	64.0	50.9		WSW
28	30.130	30.121	30.026	29.912	77.3	56.8		N			28	30.037	30.114	30.107	30.069	63.3	47.9		W
29	29.766	29.894	30.102	30.256	63.2	49.0		NNW			29	30.025	30.049	30.070	30.139	63.3	47.7		E
30	30.297	30.307	30.247	30.253	69.0	44.0		S			30	30.132	30.112	30.071	30.053	62.2	46.3		SW

JULY, 1892.

KEW.								GLASGOW.							
BAROMETER.					TEMPERA- TURE.		Direction of wind at noon	BAROMETER.				TEMPERA- TURE.		Direction of wind at noon	
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.		Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.		Min.
1	30.243	30.237	30.181	30.188	71.1	48.2	SW	1	30.044	30.055	30.057	30.061	61.1	48.4	W
2	30.145	30.110	30.009	29.939	74.9	52.4	S	2	30.001	29.902	29.806	29.729	60.2	50.4	S
3	29.821	29.709	29.680	29.780	77.0	55.7	S	3	29.664	29.629	29.590	29.587	59.8	54.0	NW
4	29.825	29.891	29.918	29.990	74.0	59.2	SW	4	29.596	29.709	29.784	29.741	60.9	50.0	W
5	30.001	29.989	29.908	29.858	66.9	52.3	SW	5	29.546	29.542	29.563	29.617	60.1	50.1	WSW
6	29.864	29.926	29.859	29.703	66.5	53.2	WSW	6	29.616	29.584	29.580	29.180	62.1	48.5	SSW
7	29.619	29.616	29.687	29.791	69.1	55.2	WSW	7	29.106	29.220	29.378	29.381	59.0	48.9	W
8	29.870	29.963	29.965	30.074	68.4	51.2	W	8	29.427	29.543	29.657	29.744	60.0	49.0	WSW
9	30.091	30.079	30.032	29.960	68.9	48.9	SSW	9	29.796	29.850	29.821	29.837	59.1	50.0	SW
10	29.938	30.002	30.008	30.020	66.0	52.3	W	10	29.904	29.978	29.982	29.994	68.1	46.0	SE
11	30.000	29.966	29.874	29.780	66.2	53.5	E	11	29.962	29.928	29.854	29.852	66.0	49.8	E
12	29.695	29.590	29.558	29.561	65.3	54.6	ENE	12	29.808	29.766	29.731	29.710	56.0	50.8	E
13	29.552	29.556	29.593	29.665	60.3	52.9	N	13	29.697	29.699	29.725	29.827	61.7	49.1	E
14	29.693	29.803	29.897	29.973	58.0	53.0	N	14	29.850	29.894	29.881	29.909	59.0	49.9	ENE
15	30.004	30.023	29.974	29.948	66.8	51.2	S	15	29.933	29.953	29.937	29.945	58.0	50.0	NE
16	29.862	29.802	29.724	29.707	69.2	51.8	SE	16	29.911	29.909	29.868	29.910	61.1	48.0	E
17	29.686	29.747	29.799	29.884	59.8	51.3	NE	17	29.880	29.892	29.873	29.883	61.2	49.0	NNW
18	29.912	29.973	29.982	29.963	60.4	50.3	N	18	29.853	29.862	29.869	29.909	62.0	47.8	WSW
19	29.963	29.896	29.647	29.535	58.8	49.0	WSW	19	29.755	29.429	29.553	29.861	59.2	50.0	NNW
20	29.561	29.843	30.039	30.167	62.4	52.2	N	20	29.991	30.103	30.113	30.148	65.5	49.1	NW
21	30.189	30.215	30.172	30.194	65.4	46.7	N	21	30.153	30.151	30.122	30.144	64.8	44.9	W
22	30.202	30.211	30.180	30.217	72.8	48.9	NW	22	30.150	30.186	30.194	30.210	61.1	51.2	W
23	30.223	30.232	30.210	30.250	73.1	53.4	NW	23	30.222	30.242	30.240	30.284	70.0	51.0	W
24	30.273	30.306	30.279	30.287	65.6	53.3	NE	24	30.296	30.305	30.273	30.282	71.0	49.8	SW
25	30.263	30.261	30.182	30.190	62.1	53.6	NE	25	30.263	30.252	30.201	30.233	71.2	49.0	W
26	30.153	30.149	30.106	30.169	68.9	54.7	NE	26	30.243	30.256	30.236	30.288	67.7	51.7	NE
27	30.169	30.183	30.176	30.212	66.4	54.1	NE	27	30.296	30.296	30.286	30.311	60.8	50.9	E
28	30.266	30.295	30.152	30.187	69.9	52.1	NNE	28	30.294	30.290	30.233	30.262	68.1	51.3	NE
29	30.190	30.192	30.120	30.153	71.3	50.0	N	29	30.253	30.264	30.210	30.221	70.0	49.9	E
30	30.128	30.129	30.088	30.069	70.1	52.6	NNE	30	30.202	30.173	30.102	30.039	68.5	51.0	W
31	30.076	30.042	29.971	29.984	73.9	53.6	W	31	29.962	29.939	29.928	29.894	66.7	57.0	WNW

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1	29.934	29.894	29.932	30.038	68.6	56.2	NW	1	29.855	29.925	30.028	30.091	67.1	55.9	NNE
2	30.100	30.118	30.106	30.124	61.7	51.9	N	2	30.044	30.068	30.044	30.036	67.7	52.9	W
3	30.101	30.080	30.017	30.017	68.3	54.1	NW	3	29.964	29.962	29.934	29.968	62.1	47.7	WNW
4	30.011	30.040	30.032	30.068	66.2	51.2	NW	4	29.975	29.997	29.988	29.983	62.5	45.0	WNW
5	30.099	30.094	30.000	29.991	70.9	45.1	SW	5	29.879	29.809	29.715	29.647	61.9	52.1	WSW
6	29.941	29.948	29.920	29.989	70.2	52.0	SW	6	29.597	29.641	29.712	29.804	59.9	48.5	WNW
7	29.948	30.000	29.920	29.970	68.7	58.3	W	7	29.827	29.875	29.864	29.829	61.9	48.0	W
8	29.903	29.858	29.759	29.757	74.3	57.5	S	8	29.738	29.731	29.780	29.885	53.0	46.7	NE
9	29.753	29.696	30.044	30.127	60.9	52.9	N	9	29.946	30.036	30.074	30.137	62.8	43.8	N
10	30.158	30.232	30.194	30.225	60.9	48.9	N	10	30.150	30.148	30.120	30.088	62.7	42.9	WSW
11	30.212	30.209	30.115	30.133	69.3	43.8	SW	11	29.980	29.963	29.946	29.950	62.1	51.4	WSW
12	30.123	30.100	29.977	29.962	71.2	49.0	SW	12	29.862	29.832	29.711	29.607	64.7	55.0	SW
13	29.844	29.744	29.725	29.738	69.9	48.0	SW	13	29.458	29.422	29.384	29.372	65.8	54.1	SW
14	29.798	29.832	29.816	29.706	70.8	57.4	SSW	14	29.375	29.436	29.436	29.337	63.2	54.0	SW
15	29.771	29.911	29.939	30.054	72.5	57.7	SW	15	29.358	29.550	29.654	29.782	62.0	52.8	SW
16	30.075	30.101	29.972	29.905	69.6	49.8	ESE	16	29.626	29.887	29.857	29.850	63.0	51.2	SW
17	29.877	29.898	29.905	29.907	79.3	56.0	SSW	17	29.811	29.866	29.899	29.928	65.7	50.1	W
18	29.864	29.754	29.779	29.646	72.1	60.4	SE	18	29.863	29.786	29.674	29.629	54.8	52.1	NE
19	29.675	29.691	29.724	29.809	65.2	60.0	N	19	29.610	29.669	29.699	29.797	64.2	45.4	W
20	29.900	30.024	30.068	30.139	71.0	52.2	WNW	20	29.841	29.883	29.879	29.871	66.2	48.4	SSW
21	30.164	30.203	30.145	30.147	72.6	49.1	S	21	29.840	29.907	29.919	29.947	69.8	59.8	SW
22	30.076	30.009	29.902	29.869	75.3	46.8	SE	22	29.909	29.805	29.840	29.809	67.1	59.7	SW
23	29.805	29.786	29.736	29.750	78.6	51.7	ESE	23	29.743	29.737	29.716	29.735	71.4	57.0	W
24	29.730	29.753	29.699	29.691	72.2	61.1	W	24	29.707	29.674	29.629	29.640	70.0	55.7	W
25	29.642	29.702	29.762	29.887	68.3	56.0	SW	25	29.621	29.630	29.639	29.692	62.7	51.0	W
26	29.626	30.003	29.982	29.989	67.8	55.0	SW	26	29.736	29.754	29.638	29.616	59.9	50.8	SW
27	29.910	29.825	29.653	29.604	64.3	53.4	SSW	27	29.499	29.440	29.401	29.401	60.0	49.0	WNW
28	29.565	29.519	29.626	29.740	67.6	52.3	NW	28	29.388	29.443	29.517	29.610	58.9	44.7	SW
29	29.737	29.686	29.613	29.600	70.1	52.2	SSW	29	29.640	29.521	29.501	29.414	55.4	38.0	E
30	29.527	29.596	29.527	29.552	69.3	59.3	SSW	30	29.282	29.244	29.171	29.141	59.9	49.9	E
31	29.562	29.592	29.651	29.783	64.3	56.1	SSW	31	29.154	29.261	29.377	29.524	59.9	49.9	N

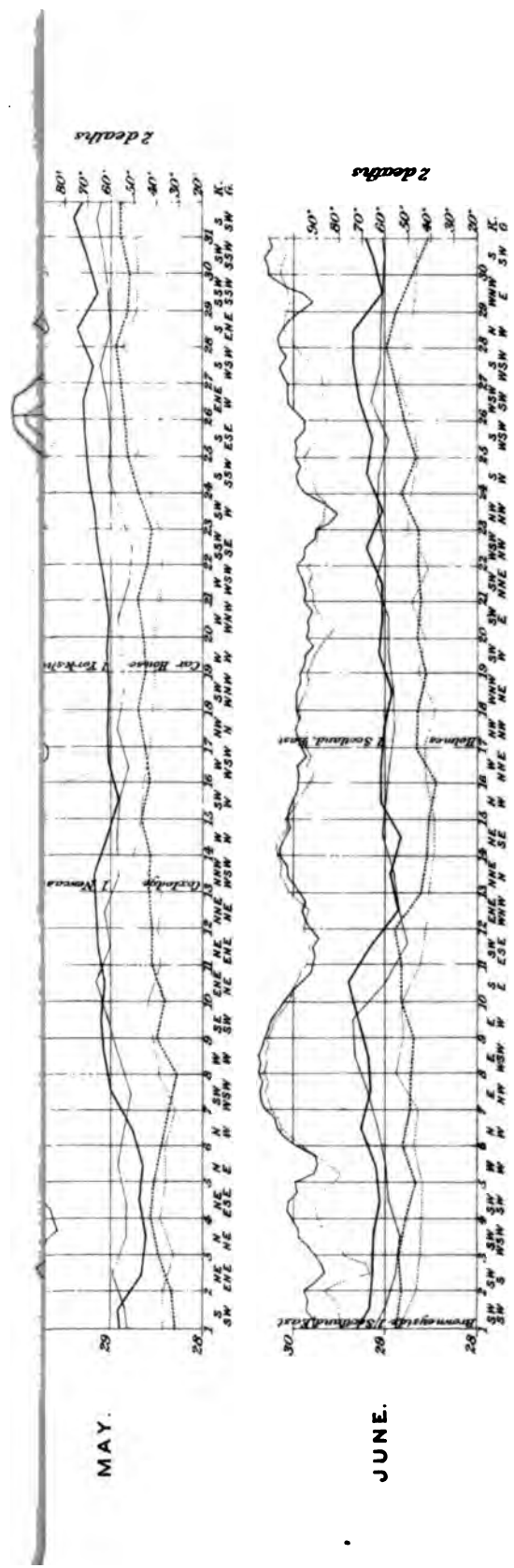
SEPTEMBER, 1892.

KEW.										GLASGOW.									
Date.	BAROMETER.				TEMPERATURE.		Direction of wind at noon			Date.	BAROMETER.				TEMPERATURE.		Direction of wind at noon		
	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.					4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.			
1	29.652	29.031	29.913	29.911	62.9	51.1	SW			1	29.539	29.453	29.469	29.441	56.2	47.0	W		
2	29.767	29.650	29.604	29.625	63.0	52.3	SSW			2	29.338	29.324	29.308	29.344	54.7	45.2	WSW		
3	29.639	29.670	29.701	29.821	60.7	47.8	W			3	29.582	29.480	29.558	29.834	57.5	45.3	WNW		
4	29.909	30.044	30.143	30.259	58.5	48.0	NNW			4	29.976	30.102	30.133	30.190	56.5	41.9	SSW		
5	30.294	30.339	30.310	30.325	61.7	39.7	SW			5	30.172	30.148	30.182	30.063	60.9	40.9	SW		
6	30.291	30.289	30.220	30.208	63.3	42.9	SW			6	30.044	30.066	30.052	29.998	62.0	49.8	W		
7	30.145	30.080	30.001	30.038	59.2	46.9	SSW			7	29.844	29.814	29.870	29.056	56.0	44.8	WSW		
8	30.013	30.018	30.004	30.008	61.9	43.1	NNW			8	30.000	30.009	29.967	29.939	58.9	41.6	SW		
9	29.971	29.959	29.938	29.969	62.0	42.4	NW			9	29.872	29.841	29.835	29.799	58.0	49.8	W		
10	29.960	30.021	30.025	30.058	61.3	55.2	SW			10	29.829	29.889	29.925	29.915	59.9	48.9	W		
11	30.069	30.092	30.028	30.077	65.4	52.9	SW			11	29.849	29.803	29.755	29.805	58.1	47.2	SW		
12	30.087	30.103	29.969	29.811	68.9	58.4	S			12	29.811	29.792	29.682	29.560	59.0	52.3	SW		
13	29.757	29.770	29.770	29.965	68.4	51.8	SW			13	29.432	29.446	29.696	29.848	59.1	46.0	W		
14	30.067	30.133	30.109	30.128	65.5	46.0	W			14	29.870	29.870	29.837	29.782	55.2	46.1	SW		
15	30.091	30.047	29.922	29.830	65.9	46.0	S			15	29.755	29.724	29.614	29.504	59.0	52.5	SSW		
16	29.716	29.727	29.829	29.969	66.6	49.8	SW			16	29.322	29.323	29.423	29.637	56.7	48.0	SW		
17	30.049	30.192	30.222	30.264	59.2	41.1	NW			17	29.872	29.966	29.972	29.918	56.0	41.5	SW		
18	30.237	30.205	30.088	30.055	63.1	33.0	S			18	29.826	29.780	29.710	29.612	56.1	50.3	SW		
19	29.981	29.997	29.963	29.982	70.9	46.0	SW			19	29.598	29.688	29.778	29.893	57.2	48.0	WSW		
20	29.946	29.914	29.843	29.901	67.9	52.0	E			20	29.659	30.063	30.096	30.151	52.0	46.1	NE		
21	29.918	29.944	29.944	30.049	66.6	55.0	N			21	30.170	30.236	30.237	30.283	52.0	40.0	ENE		
22	29.105	30.160	30.167	30.173	58.9	55.1	NNE			22	30.291	30.265	30.235	30.206	55.0	39.2	ENE		
23	30.113	30.067	30.036	29.984	65.5	53.8	WNW			23	30.103	30.008	29.843	29.694	55.5	41.4	WNW		
24	29.877	29.889	29.922	29.983	64.2	48.0	W			24	29.552	29.624	29.651	29.568	54.0	46.0	W		
25	29.947	29.943	29.901	29.974	63.0	46.6	SW			25	29.473	29.458	29.548	29.656	50.7	48.1	WSW		
26	29.937	30.022	29.911	29.839	64.6	50.0	SW			26	29.688	29.702	29.566	29.394	57.1	48.8	SSW		
27	29.752	29.706	29.632	29.591	66.3	51.9	SW			27	29.292	29.193	29.217	29.224	56.3	42.8	SW		
28	29.679	29.760	29.734	29.773	58.1	46.2	W			28	29.404	29.528	29.560	29.415	51.2	40.9	W		
29	29.796	29.784	29.640	29.591	58.3	42.6	SW			29	29.359	29.242	29.228	29.264	50.0	43.0	SW		
30	29.473	29.457	29.500	29.480	57.1	47.8	SW			30	29.230	29.240	29.244	29.270	49.4	42.0	S		

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1	29.404	29.304	29.355	29.389	55.2	42.6	SSW			1	29.271	29.284	29.271	29.246	46.8	42.4	NE		
2	29.446	29.440	29.487	29.594	49.3	39.3	ESE			2	29.350	29.414	29.479	29.569	47.8	41.9	NE		
3	29.658	29.687	29.680	29.704	55.7	41.9	WSW			3	29.641	29.675	29.662	29.625	50.1	41.4	NNW		
4	29.671	29.670	29.608	29.510	56.3	43.0	SW			4	29.581	29.598	29.567	29.538	51.8	46.0	W		
5	29.420	29.382	29.370	29.437	55.1	40.3	SW			5	29.358	29.249	29.120	29.068	49.3	43.9	W		
6	29.373	29.331	29.219	29.261	52.9	39.5	SW			6	29.113	29.158	29.130	29.109	51.7	46.0	SSW		
7	29.276	29.341	29.355	29.404	55.2	42.8	SW			7	29.165	29.196	29.226	29.309	50.0	43.7	NW		
8	29.427	29.534	29.572	29.608	51.6	42.1	WSW			8	29.338	29.403	29.373	29.226	48.2	40.2	WNW		
9	29.497	29.370	29.410	29.491	53.5	42.8	W			9	29.937	29.851	29.043	29.290	49.2	42.1	WNW		
10	29.605	29.754	29.825	29.934	55.8	39.2	W			10	29.479	29.622	29.721	29.848	51.7	38.0	NW		
11	29.660	30.033	30.025	30.017	52.5	35.6	N			11	29.915	30.015	30.052	30.109	52.9	36.3	NW		
12	29.044	30.044	29.984	29.965	50.5	31.6	NW			12	30.118	30.159	30.145	30.176	51.0	33.0	N		
13	29.913	29.887	29.806	29.741	53.3	45.5	NNE			13	30.137	30.145	30.090	30.061	50.0	45.0	NNE		
14	29.582	29.626	29.661	29.754	52.3	46.7	ESE			14	30.069	30.073	30.015	30.017	51.2	45.8	NE		
15	29.783	29.844	29.748	29.744	52.0	40.1	E			15	29.991	30.023	29.994	30.007	48.0	42.7	NE		
16	29.686	29.676	29.696	29.789	50.7	41.8	N			16	29.956	29.939	29.970	30.030	47.3	38.0	NE		
17	29.826	29.944	30.025	30.108	48.9	37.5	N			17	30.057	30.120	30.151	30.234	45.6	35.0	NNE		
18	30.114	30.209	30.224	30.274	48.0	35.5	N			18	30.272	30.310	30.265	30.274	46.9	30.1	W		
19	30.371	30.288	30.211	30.198	47.9	32.9	NNW			19	30.209	30.135	30.068	30.062	49.1	34.8	W		
20	30.132	30.081	29.995	29.932	48.0	35.5	W			20	30.027	29.969	29.873	29.767	45.0	37.8	ENE		
21	29.795	29.665	29.540	29.512	49.7	36.6	W			21	29.653	29.632	29.611	29.679	44.4	36.3	N		
22	29.494	29.586	29.611	29.598	46.0	34.7	NW			22	29.668	29.682	29.582	29.466	43.2	34.0	WNW		
23	29.558	29.591	29.611	29.603	47.7	33.5	WNW			23	29.485	29.530	29.536	29.588	45.1	34.7	NW		
24	29.711	29.752	29.782	29.831	46.3	31.0	W			24	29.679	29.735	29.783	29.826	42.1	29.3	NW		
25	29.737	29.691	29.707	29.825	42.5	35.2	NNE			25	29.821	29.842	29.843	29.912	38.0	23.8	ESE		
26	29.971	30.081	30.090	29.920	48.2	28.3	N			26	29.935	29.942	29.858	29.965	40.8	24.0	S		
27	29.741	29.592	29.453	29.372	56.9	41.6	S			27	29.949	29.259	29.185	29.065	50.0	37.9	S		
28	29.916	29.915	29.588	29.632	58.5	51.7	S			28	29.782	29.991	29.007	29.032	55.2	48.0	SW		
29	29.325	29.319	29.442	29.543	58.9	46.3	SW			29	29.973	29.926	29.935	29.903	53.2	42.7	SSW		
30	29.608	29.665	29.664	29.578	53.0	38.3	N			30	29.429	29.524	29.555	29.599	48.2	40.0	SW		
31	29.420	29.607	29.679	29.744	47.0	45.1	N			31	29.591	29.643	29.690	29.762	46.3	35.7	WNW		

DIAGRAM SHEWING THE HEIGHT OF THE BAROMETER, THE MAXIMA & MINIMA TEMPERATURES & THE DIRECTION OF THE WIND AT THE OBSERVATORIES OF KEW & GLASGOW TOGETHER WITH THE EXPLOSIONS OF FIRE-DAMP IN ENGLAND & SCOTLAND.



The *firm* top line is the Barometer reading at Kew, taken at 4 a.m. 10 a.m. 4 p.m. & 10 p.m.
The dotted top line is the Barometer reading at Glasgow taken at 4 a.m. 10 a.m. 4 p.m. & 10 p.m.
The lower lines are the Maxima & Minima Temperatures at Kew & Glasgow observed respectively at midnight & 9 p.m.
Kew lines are thick, and Glasgow lines are thin.
The figures attached to the districts, show the Number of Deaths caused by the Explosions.

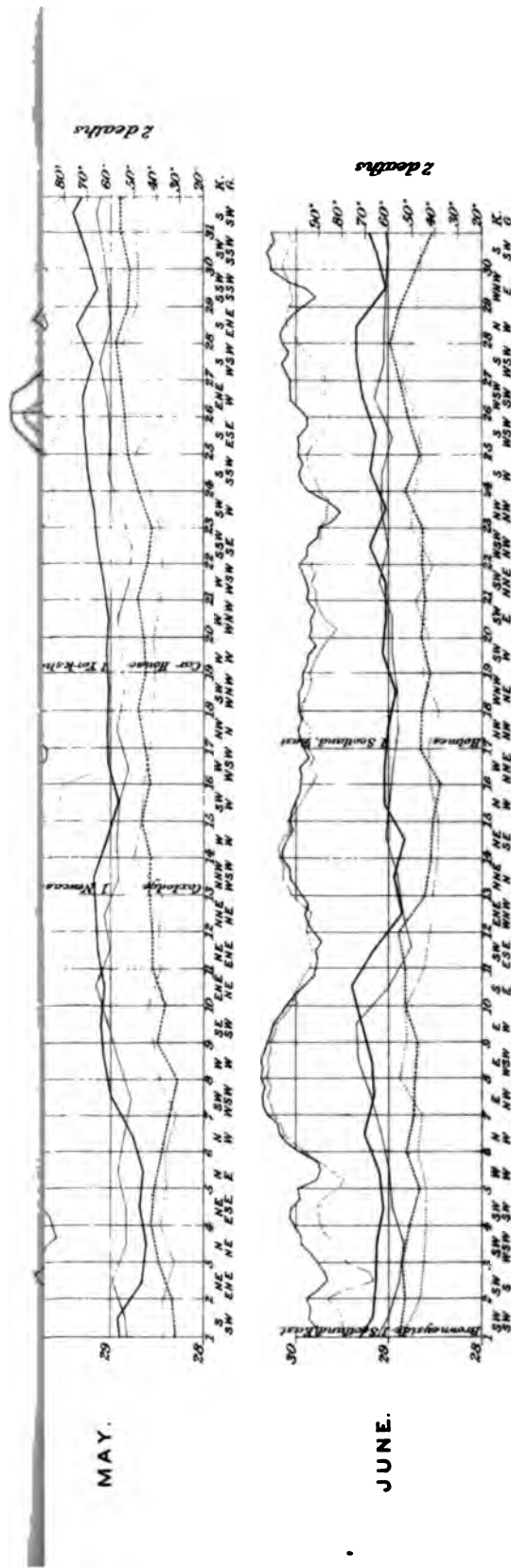
SEPTEMBER, 1892.

KEW.							GLASGOW.								
BAROMETER.					TEMPERATURE.		Direction of wind at noon	BAROMETER.					TEMPERATURE.		Direction of wind at noon
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.		Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.	
1	29.852	29.931	29.913	29.911	62.9	51.1	SW	1	29.539	29.453	29.469	29.441	56.2	47.0	W
2	29.767	29.650	29.604	29.623	63.0	52.3	SSW	2	29.338	29.324	29.308	29.344	54.7	45.2	WSW
3	29.639	29.670	29.704	29.824	60.7	47.8	W	3	29.382	29.480	29.558	29.834	57.5	45.3	WNW
4	29.900	30.044	30.143	30.259	58.5	48.0	NNW	4	29.976	30.102	30.133	30.190	56.5	41.9	SSW
5	30.294	30.339	30.310	30.325	61.7	39.7	SW	5	30.172	30.148	30.182	30.063	60.9	40.9	SW
6	30.291	30.289	30.220	30.208	63.3	42.9	SW	6	30.044	30.086	30.052	29.998	62.0	40.8	W
7	30.145	30.080	30.001	30.038	59.2	46.9	SW	7	29.834	29.811	29.870	29.956	56.0	44.8	WSW
8	30.043	30.048	30.004	30.008	61.9	43.1	NNW	8	30.000	30.009	29.967	29.939	58.9	41.6	SW
9	29.971	29.959	29.938	29.960	62.0	42.4	NW	9	29.872	29.841	29.835	29.799	58.0	49.8	W
10	29.960	30.021	30.025	30.058	64.3	55.2	SW	10	29.829	29.889	29.925	29.915	59.9	48.9	W
11	30.068	30.092	30.028	30.077	65.4	52.9	SW	11	29.849	29.803	29.755	29.805	58.1	47.2	SW
12	30.087	30.103	30.060	29.841	68.9	58.4	S	12	29.811	29.792	29.662	29.560	59.0	52.3	SW
13	29.757	29.770	29.770	29.965	68.4	54.8	SW	13	29.432	29.446	29.696	29.848	58.1	46.0	W
14	30.067	30.133	30.160	30.128	65.5	46.0	W	14	29.870	29.876	29.837	29.782	55.2	46.1	SW
15	30.091	30.017	29.922	29.830	65.9	46.9	S	15	29.755	29.724	29.614	29.501	59.0	52.5	SSW
16	29.716	29.727	29.829	29.969	66.6	49.8	SW	16	29.322	29.333	29.423	29.637	56.7	48.0	SW
17	30.049	30.192	30.222	30.264	59.2	41.1	NW	17	29.872	29.866	29.972	29.918	56.0	41.5	SW
18	30.237	30.205	30.088	30.055	63.1	33.9	S	18	29.826	29.780	29.710	29.612	56.1	50.3	SW
19	29.981	29.967	29.963	29.962	70.9	46.9	SW	19	29.598	29.688	29.778	29.893	57.2	48.0	WSW
20	29.946	29.914	29.813	29.901	67.9	52.0	E	20	29.959	30.063	30.096	30.151	52.0	46.1	NE
21	29.918	29.944	29.944	30.049	66.6	55.0	N	21	30.170	30.236	30.237	30.283	52.0	40.0	ENE
22	29.105	30.166	30.167	30.173	58.9	55.1	NNE	22	30.291	30.295	30.235	30.206	55.0	39.2	ENE
23	30.113	30.197	30.036	29.984	63.5	53.8	WNW	23	30.103	30.008	29.843	29.694	55.5	41.4	WNW
24	29.877	29.889	29.922	29.983	64.2	48.0	W	24	29.552	29.624	29.651	29.568	54.0	46.0	W
25	29.947	29.943	29.901	29.974	63.0	46.6	SW	25	29.473	29.458	29.548	29.656	56.7	48.1	WSW
26	29.997	30.022	29.911	29.839	64.6	50.0	SW	26	29.688	29.702	29.566	29.394	57.1	48.8	SSW
27	29.752	29.708	29.632	29.591	66.3	51.9	SW	27	29.202	29.193	29.217	29.224	56.3	42.8	SW
28	29.679	29.700	29.734	29.773	58.1	46.2	W	28	29.404	29.528	29.500	29.415	51.2	40.9	W
29	29.796	29.784	29.640	29.591	58.3	42.6	SW	29	29.259	29.242	29.228	29.264	50.0	43.0	SW
30	29.473	29.457	29.500	29.480	57.1	47.8	SW	30	29.230	29.240	29.244	29.270	49.4	42.0	S

OCTOBER, 1892.

1	29.404	29.361	29.355	29.389	55.2	42.6	SSW	1	29.271	29.284	29.271	29.246	48.8	42.4	NE
2	29.446	29.440	29.487	29.504	49.3	39.3	ESE	2	29.350	29.414	29.479	29.569	47.8	41.9	NE
3	29.658	29.687	29.680	29.701	55.7	41.9	WSW	3	29.641	29.675	29.662	29.625	50.1	41.4	NNW
4	29.671	29.670	29.608	29.510	56.3	43.0	NW	4	29.581	29.568	29.567	29.538	51.8	46.0	W
5	29.420	29.382	29.370	29.437	55.1	40.3	SW	5	29.388	29.240	29.120	29.068	49.3	43.9	W
6	29.373	29.331	29.219	29.264	52.9	39.5	SW	6	29.113	29.158	29.150	29.169	51.7	46.0	SSW
7	29.276	29.341	29.355	29.404	55.2	42.8	SW	7	29.155	29.196	29.226	29.309	50.0	43.7	NW
8	29.427	29.534	29.572	29.608	51.6	42.1	W-SW	8	29.338	29.403	29.373	29.226	48.2	40.2	WNW
9	29.497	29.370	29.410	29.494	53.5	42.8	W	9	29.937	29.851	29.043	29.290	49.2	42.1	WNW
10	29.605	29.754	29.828	29.934	55.8	39.2	W	10	29.479	29.622	29.724	29.848	51.7	38.0	NW
11	29.880	30.033	30.025	30.047	52.5	35.6	NW	11	29.915	30.015	30.052	30.109	52.9	36.3	NW
12	30.044	30.044	29.981	29.965	50.5	34.6	N	12	30.118	30.159	30.145	30.176	51.0	33.0	N
13	29.913	29.887	29.806	29.741	53.3	45.5	NNE	13	30.137	30.145	30.090	30.091	50.0	45.0	NNE
14	29.582	29.626	29.661	29.751	52.3	46.7	ESE	14	30.069	30.073	30.015	30.017	51.2	45.8	NE
15	29.783	29.804	29.748	29.741	52.0	40.1	E	15	29.991	30.023	29.994	30.007	48.0	43.7	NE
16	29.686	29.676	29.696	29.780	50.7	41.8	N	16	29.956	29.939	29.970	30.030	47.3	38.0	NE
17	29.826	29.944	30.023	30.108	48.9	37.5	N	17	30.067	30.120	30.151	30.234	45.6	35.0	NNE
18	30.144	30.209	30.224	30.274	48.0	35.5	N	18	30.272	30.310	30.285	30.274	46.9	30.1	W
19	30.271	30.288	30.211	30.198	47.9	32.9	NNW	19	30.209	30.135	30.068	30.092	49.1	34.8	W
20	30.132	30.081	29.995	29.932	48.0	35.5	W	20	30.027	29.960	29.873	29.767	45.0	37.8	ENE
21	29.705	29.665	29.340	29.512	49.7	38.6	W	21	29.653	29.632	29.611	29.679	44.4	36.3	N
22	29.494	29.586	29.611	29.596	46.0	34.7	NW	22	29.608	29.622	29.532	29.496	43.2	34.0	WNW
23	29.555	29.591	29.611	29.693	47.7	33.5	WNW	23	29.485	29.539	29.536	29.588	45.1	34.7	NW
24	29.711	29.752	29.782	29.831	46.3	31.0	W	24	29.679	29.755	29.783	29.826	42.1	29.3	NW
25	29.737	29.691	29.707	29.825	42.5	35.2	NNE	25	29.821	29.842	29.843	29.912	38.0	23.8	ESE
26	29.971	30.081	30.030	29.820	48.2	28.3	N	26	29.635	29.942	29.858	29.663	40.8	24.0	S
27	29.741	29.562	29.453	29.372	56.9	11.6	S	27	29.399	29.259	29.185	29.065	50.0	37.9	S
28	29.316	29.315	29.258	29.332	58.5	54.7	S	28	29.882	29.991	29.007	29.032	55.2	48.0	SW
29	29.328	29.349	29.442	29.431	58.9	46.3	SW	29	29.973	29.926	29.935	29.903	53.2	42.7	SSW
30	29.608	29.695	29.661	29.578	53.0	38.3	N	30	29.429	29.524	29.555	29.599	48.2	40.0	SW
31	29.480	29.607	29.679	29.744	47.0	45.1	N	31	29.591	29.643	29.690	29.762	46.3	35.7	WNW

DIAGRAM SHewing THE HEIGHT OF THE BAROMETER, THE MAXIMA & MINIMA TEMPERATURES & THE DIRECTION OF THE WIND AT THE OBSERVATORIES OF KEW & GLASGOW TOGETHER WITH THE EXPLOSIONS OF FIRE-DAMP IN ENGLAND & SCOTLAND.



The firm top line is the Barometer reading at Kew taken at 4 a.m. 10 a.m. 4 p.m. & 10 p.m.
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 The lower lines are the Maxima & Minima Temperatures at Kew & Glasgow, observed respectively at midnight & 9 p.m.
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 Transactions 1892-3

And "Red Sea" "Litho Engraving"

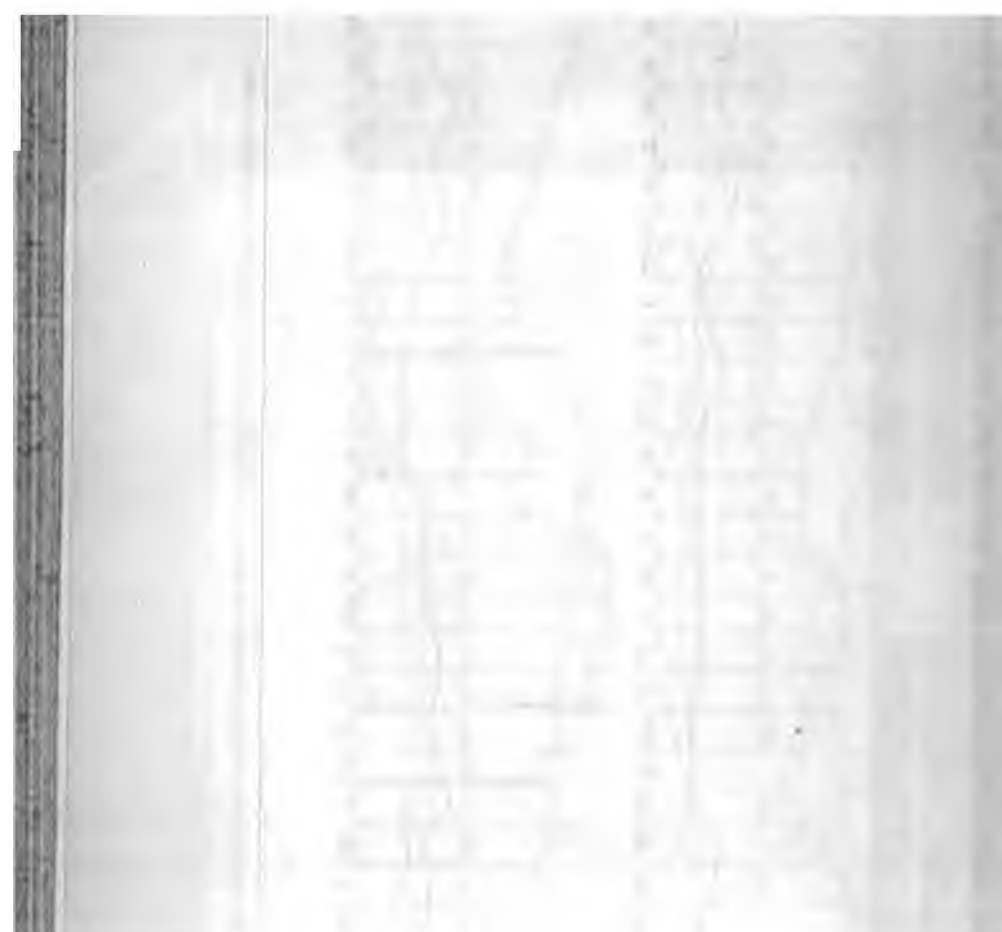


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The lower lines are the *Marina* & *Minima* Temperatures at Kew & Glasgow, observed respectively at midday & 7 p.m.
Kew lines are thick, and Glasgow lines are thin.
The figures attached to the districts, show the Number of Deaths caused by the Explosions.

North of England Institute of Mechanical Engineering
 Trans. 1913-14, p. 4982

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NOVEMBER, 1892.

KEW.									GLASGOW.								
BAROMETER.									BAROMETER.								
Date.					TEMPERATURE.		Direction of wind at noon		Date.					TEMPERATURE.		Direction of wind at noon	
	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.				4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.		
1	29.765	29.816	29.822	29.852	48.9	34.9	N		1	29.792	29.833	29.810	29.798	44.3	30.4	NE	
2	29.848	29.832	29.694	29.605	50.7	30.0	N		2	29.711	29.614	29.427	29.392	44.3	35.9	ESE	
3	29.607	29.674	29.787	29.896	54.7	41.9	W		3	29.294	29.347	29.403	29.596	50.4	44.9	SW	
4	29.878	29.862	29.817	29.792	58.0	42.2	S		4	29.482	29.415	29.446	29.484	55.0	47.6	SSW	
5	29.831	29.873	29.839	29.830	57.2	50.5	SSW		5	29.456	29.487	29.580	29.668	52.1	45.8	SW	
6	29.813	29.855	29.899	29.906	53.3	40.3	W		6	29.695	29.788	29.851	29.948	48.0	38.9	W	
7	30.044	30.133	30.161	30.242	49.8	32.9	WNW		7	30.014	30.082	30.068	30.052	47.8	33.8	ENE	
8	30.277	30.321	30.282	30.277	43.9	33.9	N		8	29.982	29.961	29.890	29.884	50.1	44.7	SSW	
9	30.221	30.179	30.129	30.122	49.4	43.3	SE		9	29.859	29.857	29.881	29.951	51.0	41.9	SW	
10	30.114	30.148	30.131	30.146	48.9	37.0	SE		10	29.964	29.966	29.959	29.976	48.3	38.9	SW	
11	30.131	30.120	30.072	30.048	47.9	36.3	W		11	29.930	29.936	29.931	29.951	52.8	44.7	SW	
12	30.000	29.981	29.915	29.905	50.4	42.2	SSW		12	29.903	29.849	29.738	29.657	48.5	43.3	S	
13	29.841	29.825	29.776	29.780	54.9	44.1	S		13	29.617	29.610	29.577	29.617	47.8	42.9	WSW	
14	29.785	29.705	29.728	29.689	60.1	51.1	S		14	29.599	29.531	29.349	29.200	54.9	42.7	ENE	
15	29.664	29.727	29.756	29.762	56.7	49.9	W		15	29.201	29.398	29.576	29.689	50.9	40.2	WSW	
16	29.687	29.755	29.790	29.880	54.0	47.0	N		16	29.710	29.775	29.797	29.879	43.2	34.0	N	
17	29.953	30.006	29.977	29.984	47.2	38.8	N		17	29.930	29.930	29.897	29.880	45.3	35.8	SE	
18	29.951	29.932	29.840	29.783	43.4	42.9	SW		18	29.811	29.806	29.728	29.685	43.3	36.2	ENE	
19	29.692	29.689	29.694	29.749	49.7	36.0	SE		19	29.612	29.624	29.664	29.742	40.7	34.0	E	
20	29.817	29.991	30.037	30.176	45.9	33.8	WSW		20	29.814	29.929	30.010	30.143	46.1	40.0	ENE	
21	30.224	30.307	30.302	30.355	45.1	34.5	WSW		21	30.208	30.305	30.314	30.351	44.7	42.0	ENE	
22	30.340	30.340	30.302	30.291	44.4	41.7	E		22	30.334	30.367	30.335	30.331	43.3	38.0	ENE	
23	30.267	30.289	30.254	30.242	44.5	39.4	E		23	30.297	30.291	30.222	30.190	42.0	36.6	ENE	
24	30.191	30.195	30.147	30.168	43.5	38.4	SE		24	30.122	30.131	30.140	30.158	39.3	37.8	ENE	
25	30.168	30.193	30.165	30.179	41.7	35.3	E		25	30.146	30.159	30.094	30.031	43.0	38.1	E	
26	30.178	30.158	30.060	30.141	50.1	40.9	S		26	29.899	29.806	29.933	30.100	46.0	39.8	NW	
27	30.219	30.372	30.419	30.456	48.9	40.1	N		27	30.150	30.154	30.161	30.151	57.1	42.1	WSW	
28	30.432	30.436	30.348	30.260	48.0	42.7	W		28	30.085	30.014	29.853	29.617	52.0	47.4	SW	
29	30.160	30.086	30.014	30.009	52.4	41.7	SW		29	29.671	29.744	29.632	29.662	49.0	33.3	WSW	
30	30.029	30.140	30.198	30.217	43.2	38.8	WNW		30	29.760	29.980	29.976	29.926	37.6	32.3	W	

DECEMBER, 1892.

1	30.111	30.000	29.674	29.795	50.1	34.7	SW		1	29.816	29.756	29.790	29.892	36.0	24.9	ENE	
2	29.998	30.154	30.120	30.036	39.5	32.2	N		2	30.010	30.110	30.049	29.903	27.0	19.0	ENE	
3	29.784	29.628	29.522	29.511	50.7	37.1	SW		3	29.613	29.349	29.257	29.267	39.4	23.9	WSW	
4	29.523	29.603	29.664	29.710	39.8	31.2	WNW		4	29.311	29.457	29.483	29.545	31.5	26.5	W	
5	29.072	29.713	29.683	29.738	36.2	29.9	WNW		5	29.589	29.578	29.524	29.604	34.8	26.5	NW	
6	29.757	29.827	29.854	29.846	39.0	28.8	W		6	29.643	29.677	29.816	29.940	40.8	33.8	NW	
7	29.878	29.983	30.060	30.137	39.9	34.5	N		7	30.061	30.166	30.177	30.215	38.1	31.2	NNE	
8	30.189	30.237	30.152	29.989	38.1	32.7	WNW		8	30.214	30.132	29.888	29.652	36.0	28.0	NE	
9	29.555	29.606	29.711	29.835	41.4	32.8	N		9	29.765	29.988	29.953	29.991	35.2	27.0	NW	
10	29.918	30.007	29.935	29.738	40.7	31.9	NNW		10	29.023	29.773	29.467	29.273	41.9	24.8	SW	
11	29.503	29.434	29.404	29.450	45.3	40.1	W		11	29.148	29.063	29.104	29.224	41.6	36.0	WSW	
12	29.511	29.523	29.492	29.617	43.9	35.3	SW		12	29.271	29.343	29.443	29.519	39.3	33.2	WNW	
13	29.749	29.921	30.051	30.153	41.1	31.1	NW		13	29.704	29.872	29.928	29.892	37.8	32.0	W	
14	30.150	30.059	29.961	29.993	50.1	31.3	SW		14	29.686	29.645	29.722	29.801	46.3	32.9	WNW	
15	30.019	30.022	30.029	30.172	54.0	47.0	W		15	29.782	29.734	29.629	29.989	45.2	42.7	WSW	
16	30.099	30.339	30.299	30.290	49.9	36.0	SW		16	30.090	30.033	29.887	29.827	48.6	39.1	SSW	
17	30.279	30.300	30.308	30.315	49.1	47.1	WSW		17	29.859	29.952	29.956	29.866	51.0	46.9	W	
18	30.273	30.277	30.239	30.253	48.5	46.6	WSW		18	29.776	29.883	29.890	29.932	50.9	45.8	W	
19	30.215	30.199	30.122	30.109	46.6	42.1	WSW		19	29.946	29.952	29.939	29.946	47.8	45.0	NW	
20	30.063	30.064	30.054	30.077	43.6	41.2	W		20	29.953	30.015	30.014	30.017	45.0	38.8	ENE	
21	30.072	30.098	30.079	30.087	41.5	31.5	NNW		21	30.011	30.012	29.985	29.999	41.1	39.2	ENE	
22	30.060	30.045	30.011	30.030	40.8	31.3	ENE		22	29.978	29.963	29.962	30.025	41.5	38.9	E	
23	30.029	30.073	30.042	30.038	38.9	30.9	ESE		23	30.036	30.074	30.035	30.018	39.1	30.9	ESE	
24	29.998	29.997	29.980	29.958	33.3	27.1	ESE		24	29.962	29.957	29.912	29.886	31.6	26.7	E	
25	29.893	29.902	29.909	29.974	32.9	26.4	E		25	29.861	29.892	29.925	30.011	26.7	20.0	NE	
26	30.036	30.106	30.122	30.161	33.7	22.5	E		26	30.042	30.090	30.102	30.145	30.0	17.2	WSW	
27	30.173	30.242	30.238	30.307	32.2	17.9	E		27	30.149	30.197	30.192	30.215	31.0	19.3	WNW	
28	30.299	30.325	30.256	30.195	28.3	24.4	E		28	30.173	30.149	30.041	29.987	38.7	28.5	SW	
29	30.085	30.020	29.935	29.884	33.5	20.3	N		29	29.964	29.801	29.743	29.726	40.1	37.0	E	
30	29.861	29.849	29.813	29.802	32.2	19.9	SE		30	29.720	29.725	29.727	29.753	38.7	30.5	E	
31	29.796	29.605	29.799	29.653	34.6	21.9	E		31	29.816	29.654	29.674	29.916	36.1	26.9	E	



NOVEMBER, 1892.

KEW.								GLASGOW.							
BAROMETER.					TEMPERATURE.		Direction of wind at noon	BAROMETER.					TEMPERATURE.		Direction of wind at noon
Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.		Date.	4 A.M.	10 A.M.	4 P.M.	10 P.M.	Max.	Min.	
1	29.765	29.816	29.822	29.852	48.9	34.9	N	1	29.792	29.833	29.810	29.798	44.3	30.4	NE
2	29.848	29.832	29.694	29.605	50.7	30.0	N	2	29.711	29.614	29.427	29.392	44.3	35.9	ESE
3	29.607	29.674	29.787	29.896	54.7	41.9	W	3	29.294	29.347	29.493	29.596	50.4	44.9	SW
4	29.878	29.802	29.817	29.792	58.0	42.2	S	4	29.482	29.415	29.446	29.484	55.0	47.6	SSW
5	29.831	29.873	29.830	29.830	57.2	50.5	SSW	5	29.456	29.487	29.580	29.668	52.1	45.8	SW
6	29.813	29.855	29.899	29.896	53.3	40.3	W	6	29.695	29.788	29.851	29.948	48.0	38.9	W
7	30.044	30.133	30.161	30.242	49.8	32.9	WNW	7	30.014	30.082	30.068	30.052	47.8	33.8	ENE
8	30.277	30.321	30.282	30.277	43.9	33.9	N	8	29.982	29.961	29.890	29.884	50.1	44.7	SSW
9	30.221	30.179	30.129	30.122	49.4	43.3	SE	9	29.859	29.857	29.981	29.951	51.0	41.9	SW
10	30.114	30.148	30.131	30.146	48.9	37.0	SE	10	29.964	29.996	29.959	29.976	48.3	38.9	SW
11	30.131	30.120	30.072	30.048	47.9	36.3	W	11	29.930	29.936	29.931	29.951	52.8	44.7	SW
12	30.000	29.981	29.915	29.905	50.4	42.2	SSW	12	29.903	29.849	29.738	29.657	48.5	43.3	S
13	29.841	29.825	29.776	29.780	54.9	44.1	S	13	29.617	29.610	29.577	29.617	47.8	42.9	WSW
14	29.785	29.705	29.728	29.689	60.1	51.1	S	14	29.569	29.531	29.349	29.200	54.9	42.7	ESE
15	29.664	29.727	29.756	29.762	56.7	49.9	W	15	29.201	29.398	29.576	29.689	50.9	40.2	WSW
16	29.687	29.755	29.790	29.880	54.0	47.0	N	16	29.710	29.775	29.797	29.879	43.2	34.0	NE
17	29.953	30.006	29.977	29.984	47.2	38.8	N	17	29.930	29.939	29.937	29.980	45.3	35.8	SE
18	29.951	29.932	29.840	29.783	43.4	42.9	SW	18	29.811	29.796	29.726	29.685	43.3	36.2	ENE
19	29.692	29.689	29.694	29.749	49.7	36.0	SE	19	29.612	29.624	29.664	29.742	40.7	34.0	E
20	29.817	29.901	30.037	30.176	45.9	33.8	WSW	20	29.814	29.929	30.010	30.143	46.1	40.0	E
21	30.224	30.307	30.362	30.355	45.1	34.5	WSW	21	30.208	30.305	30.314	30.351	44.7	42.0	ENE
22	30.340	30.340	30.362	30.291	44.4	41.7	E	22	30.334	30.367	30.335	30.331	43.3	38.0	ENE
23	30.267	30.289	30.254	30.242	44.5	39.4	E	23	30.297	30.291	30.222	30.190	42.0	36.6	ENE
24	30.191	30.195	30.147	30.168	43.5	38.4	SE	24	30.122	30.131	30.140	30.158	39.3	37.6	ENE
25	30.168	30.193	30.165	30.179	44.7	35.3	E	25	30.146	30.150	30.094	30.031	43.0	38.1	E
26	30.178	30.158	30.060	30.141	50.1	40.9	S	26	29.969	29.806	29.833	30.160	46.8	39.8	NW
27	30.219	30.372	30.419	30.456	48.9	40.1	N	27	30.150	30.154	30.161	30.151	51.1	42.1	WSW
28	30.432	30.436	30.348	30.260	48.0	42.7	W	28	30.095	30.014	29.853	29.617	52.0	47.4	SW
29	30.160	30.086	30.014	30.009	52.4	41.7	SW	29	29.671	29.744	29.632	29.662	49.0	33.3	WSW
30	30.029	30.140	30.196	30.217	43.2	38.8	WNW	30	29.760	29.980	29.976	29.926	37.6	32.3	W

DECEMBER, 1892.

1	30.111	30.000	29.674	29.795	50.1	34.7	SW	1	29.816	29.756	29.790	29.892	36.0	24.9	ENE	
2	29.998	30.154	30.129	30.036	39.5	32.2	N	2	30.010	30.110	30.049	29.903	27.0	19.0	ENE	
3	29.784	29.628	29.522	29.511	50.7	37.1	N	3	29.612	29.349	29.257	29.267	39.4	23.9	WSW	
4	29.523	29.603	29.664	29.710	39.8	31.2	WNW	4	29.311	29.457	29.483	29.545	31.5	26.5	W	
5	29.672	29.713	29.683	29.738	39.2	29.9	WNW	5	29.589	29.578	29.524	29.604	34.8	26.5	NW	
6	29.757	29.827	29.854	29.846	39.0	28.8	W	6	29.643	29.677	29.816	29.940	40.8	33.8	NW	
7	29.878	29.983	30.060	30.137	39.9	34.5	N	7	30.061	30.166	30.177	30.215	38.1	31.2	NNE	
8	30.189	30.237	30.152	29.989	38.1	32.7	WNW	8	30.214	30.132	29.888	29.653	36.0	28.0	NW	
9	29.555	29.606	29.711	29.835	41.4	32.8	N	9	29.765	29.888	29.953	29.991	35.2	27.0	N	
10	29.918	30.007	29.935	29.738	40.7	31.9	NNW	10	29.923	29.773	29.467	29.273	41.9	24.8	SW	
11	29.503	29.434	29.404	29.450	45.3	40.1	W	11	29.148	29.083	29.104	29.224	41.6	36.0	WSW	
12	29.511	29.523	29.492	29.647	43.9	35.3	SW	12	29.271	29.343	29.443	29.519	39.3	33.2	WNW	
13	29.749	29.921	30.031	30.153	41.1	31.1	NW	13	29.704	29.872	29.928	29.892	37.8	32.0	W	
14	30.150	30.059	29.961	29.993	50.1	31.3	SW	14	29.686	29.648	29.722	29.801	46.3	36.9	WNW	
15	30.019	30.622	30.029	30.172	54.0	47.0	W	15	29.782	29.734	29.829	29.989	45.2	42.7	WSW	
16	30.299	30.339	30.299	30.290	49.9	36.0	SW	16	30.090	30.033	29.887	29.827	48.8	39.1	SSW	
17	30.279	30.300	30.308	30.315	49.1	47.1	WSW	17	29.859	29.952	29.956	29.886	51.0	46.9	W	
18	30.273	30.277	30.239	30.253	48.5	46.6	WSW	18	29.776	29.883	29.899	29.932	50.9	45.8	W	
19	30.215	30.199	30.122	30.109	46.6	42.1	WSW	19	29.946	29.932	29.939	29.946	47.8	45.0	NW	
20	30.063	30.084	30.054	30.077	43.6	41.2	W	20	29.953	30.015	30.014	30.017	45.0	38.8	ENE	
21	30.072	30.098	30.079	30.087	41.5	31.5	NNW	21	30.011	30.012	29.995	29.999	41.1	39.2	ENE	
22	30.060	30.045	30.011	30.030	40.8	31.3	ENE	22	29.978	29.993	29.992	30.025	41.5	38.9	E	
23	30.029	30.073	30.042	30.038	38.9	30.9	ESE	23	30.036	30.074	30.035	30.018	39.1	30.9	ESE	
24	29.998	29.997	29.960	29.958	33.3	27.1	ESE	24	29.962	29.957	29.912	29.886	31.6	26.7	E	
25	29.893	29.902	29.909	29.974	32.9	26.4	E	25	29.861	29.892	29.928	30.011	26.7	20.0	NE	
26	30.036	30.106	30.122	30.161	33.7	22.5	E	26	30.042	30.090	30.102	30.145	30.0	17.2	WSW	
27	30.173	30.242	30.258	30.307	32.2	17.9	E	27	30.149	30.197	30.192	30.215	31.0	19.3	WNW	
28	30.299	30.325	30.256	30.195	28.3	24.4	E	28	30.173	30.149	30.041	29.987	38.7	28.5	SW	
29	30.085	30.020	29.935	29.894	33.5	20.3	K	29	29.864	29.801	29.743	29.726	40.1	37.0	S	
30	29.861	29.849	29.813	29.802	32.2	19.9	SE	30	29.720	29.723	29.727	29.753	38.7	30.5	E	
31	29.796	29.805	29.799	29.853	34.6	21.9	E	31	29.816	29.854	29.874	29.916	36.1	26.9	E	

II.—REPORT OF THE PRUSSIAN FIRE-DAMP COMMISSION.*

SECOND PART.—*Continued.*†

SCIENTIFIC AND TECHNICAL ENQUIRIES.

B.—THE MEANS AND METHODS OF COMBATING FIRE-DAMP.

I.—RECOGNITION OF FIRE-DAMP.

98.—*Fire-damp Indicators.*—A whole series of so-called gas or fire-damp indicators have been devised, whose main object is to make manifest the presence of carburetted hydrogens in the atmosphere of the workings, automatically and therefore independently of the greater or less attentiveness of the miners.‡ They are all of them based on the utilization of certain physical or chemical properties of pit-gas; as, for instance, the indicators of Mr. Ansell and Mr. Van der Weide, based on the diffusion of gas brought about by endosmosis; the acoustic indicator of Mr. Forbes and Mr. Blaikley, the instruments devised by Messrs. Wilson, Carleton, and others, based on the difference of specific gravity of the gaseous mixtures; the thermoscopic instruments of Messrs. Angus Smith, Aitken, Somzée, Siemens, and Halske, based on the condensation [occlusion] of the gas by platinum sponge, and the consequent rise of temperature or difference of pressure; the electro-photometric indicator of Mr. Liveing, based on the increased intensity of glow in the gas of a platinum spiral through which an electric current is conducted; the methanometer of Mr. Mounier, as well as the grisoumeter of Mr. Coquillion and Mr. Maurice, based on the combustion of the gas by means of electrically incandescent platinum or palladium wire, and the consequent diminution of volume or tension. Finally, other instruments are based on the differential conductivity of the gases for heat (Somzée), on the transmission of the pressure arising from the explosion of the gas by an electric spark (Kitsee), on the application of the lengthening of the lamp-flame, which is a consequence of the presence of fire-damp, to the combustion of a thread connected with an alarm bell (Turquan), on the production of so-called singing flames (Irvine), on the heating and expansion of a metal rod (Clermont), and so on.

Almost all the indicators above enumerated are fixtures, and are so arranged that, when they come into action, they close an electric circuit, which starts alarm bells ringing, or gives other signals, or provides a continuous graphic record of the state of the atmosphere in the mine; this, either at definite observation points

* Translated by Mr. L. L. Belinfante. † *Trans. Fed. Inst.*, vol. iii., page 1105; and vol. iv., page 631.

‡ Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig. pages 173-174; Messrs. Mallard and Le Chatelier, "On the Detection of Fire-damp in the Air of Mines." *Annales des Mines*, March-April, 1881; Mr. L. Somzée, *Means of Preventing Explosions in Mines*, Schaerbeck, 1881; Prof. Kretschmer, "Preliminary Report of the British Royal Commission on Accidents in Mines," *loc. jam. cit.* pages 33-36; Mr. Hoernecke, "On Precautionary Measures against Fire damp," etc., *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxi., B., pages 291-293; Dr. Serio, *Treatise on Mining*, 4th edition, 1864, vol. II., pages 314-319; Sir Fred. Abel, *Address*, *loc. jam. cit.*, pages 16-17 *Final Report of the British Royal Commission*, pages 97-107.

above bank (manager's office, etc.), or even below ground (generally at the onset). But the essential point is that they only offer the means of watching the ventilation at particular localities or narrowly restricted portions of the pit (the points where they are placed), and that the use of such indicators can at no time enable one to dispense with the usual exhaustive examination of the workings for fire-damp by officials and miners. Under these circumstances, the value in mining practice of nearly everyone of the above-mentioned indicators is, to say the least, exceedingly doubtful; and, in fact, none of them has been so far brought into general use.

99.—Safety-lamps.—After all, for the recognition of the presence of fire-damp, the handiest and best means available is the safety-lamp. Not only is it everywhere at hand in fiery mines, on account of its use for lighting, but its characteristics and the method of handling it are familiar to every miner. Moreover, it is so easily carried from one place to another, that the miner may use it to examine at once any particular spot, whether in riding [up and down the pit] or at the working-face. Finally, the lamp is sufficiently sensitive to draw the attention of the pitman (if he be not extraordinarily careless) in good time to the fact that fire-damp is present, and so acts as a warning signal against pressing danger.

The warning given by the safety-lamp consists, as everyone knows, in the striking changes undergone by the lamp-flame in consequence of the presence of pit-gas. These changes are two-fold: (*a*) formation of a bluish cone of light or halo (aureole); and (*b*) lengthening of the flame. To observe them accurately, it is needful that the height of the flame be diminished in as great a measure as possible. As a covering for the illuminating flame, a small movable shield or hood is found very serviceable.* The preliminary test with large flame proposed by Mr. Marsaut (he based his proposal on grounds of safety) cannot be regarded as sufficient.†

In ordinary safety-lamps the peculiar flame phenomena‡ are noticeable, for a practised eye, in mixtures containing as little as 2 per cent. methane, but it takes 2½ to 3 per cent. of fire-damp to make these phenomena generally unmistakable. Of all the forms of lamps most used thus far in Prussian coal-mines, the Davy lamp betrays the flame-phenomena most clearly because it has no glass cylinder: and so it was long used in preference to any other lamp in examining the workings for fire-damp. The researches of the Commission tend to prove, however, that the Boty lamp (Saarbrück) and the Wolf benzine-lamp compete very closely with the Davy in this respect.§ The benzine-lamp has this advantage over lamps burning rape-oil, that it yields taller cones of flame: further, the accurate arrangement of the wick offers by no means such great difficulties in the former as in the latter. The least suitable of any is the Mueseler lamp—particularly that variety which has a chimney reaching far up into the glass-cylinder, for its indications are tardy, and the most striking flame-phenomena are partly concealed by the chimney. And so too do the lamps which are provided with a protective hood thereby lose some of their indicating capabilities.

The idea which was at one time put forward|| that the presence of carbon dioxide in the atmosphere of the pit would affect detrimentally the lamps con-

* Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig. page 172; *Final Report of the French Fire-damp Commission*, German translation, *op. jam. cit.*, page 296.

† Compare *Appendices*, vol. iii. page 74.

‡ Mr. Pfähler, "Ventilation in the Royal Colliery of Sulzbach-Altenwald, near Saarbrück," *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xx., B., pages 53-54; Messrs. Mallard and Le Chatelier, "On the Detection of Fire-damp, etc.," *op. jam. cit.*; Mr. Hoernecke, "On Precautionary Measures against Fire damp," etc., *op. jam. cit.* page 293; Messrs. Kreischer and Winkler, "Researches on Safety-lamps," *Jahrb. f. d. Berg- u. Hüttenwesen im Königr. Sachsen*, 1884, pages 52-77.

§ *Appendices*, vol. iii., pages 171-173.

|| Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig. page 171.

sidered as indicators, was afterwards shown to be erroneous by Messrs. Mallard and Le Chatelier;* these observers found that the presence of 3 or 4 per cent. carbon dioxide in no way affects the flame-phenomena of the lamp. Similarly, in the course of the researches conducted by the Commission at Bochum, the highest percentages of carbon dioxide (1.75 per cent.) hitherto observed in working the mines were proved to have no effect.†

An obvious defect of the safety-lamp, from the point of view of its use in the recognition of fire-damp, is that it only begins to show unmistakably the presence of the dangerous gas, and to allow of its volume being estimated, when the proportion of methane exceeds $2\frac{1}{2}$ to 3 per cent., that is when the peril has already assumed an alarming aspect. On the other hand, with smaller proportions of dangerous gas, the safety-lamp leaves the ordinary observer completely in the lurch. And yet more stress than ever must be laid on the importance of recognizing immediately even very small quantities of fire-damp in pit-workings, now that the experiments conducted by the Commission at Neunkirchen (compare pars. Nos. 76 and 77 of this Report) have taught us that in presence of coal-dust the existence of a merely insignificant amount of gas in the surrounding atmosphere greatly enhances the risk of explosion.

By supplying the safety-lamp with pure hydrogen gas‡ Messrs. Mallard and Le Chatelier were able to trace the presence in the pit of even so small a proportion as $\frac{1}{4}$ per cent. of methane. Mr. Pieler, working on the same lines,§ that is, obtaining a flame as colourless as possible, and eliminating the combustion-products of oil (which play the part of disturbing factors in the recognition of small volumes of gas) produced in his spirit lamp an extremely serviceable appliance for the practical examination of mines; with it, the presence of dangerous gases in a proportion of less than 3 per cent.—that is, a proportion too small to be detected by an ordinary safety-lamp—can be determined with approximate accuracy. The Pieler lamp is a simple Davy lamp of large size, with the following modifications: instead of the customary rape-oil, alcohol is used to feed the flame; and further, to facilitate the exact estimation of the flame-height, a small tapering cone is placed over the burner. The large size of the lamp is purposely selected with a view to full development of the cone of flame. The numerous experiments conducted at the instance of the Commission|| have shown that the flame-phenomena of the Pieler lamp are so distinct that they permit of the estimation of the gas-content, even when the percentage is as low as $\frac{1}{4}$ per cent., and, moreover the experimental error does not exceed 0.25 per cent. It is shown too that the lamp is a most useful indicator just at the point where the ordinary safety-lamp ceases to be of any value for such purposes. On the other hand, one is compelled to admit the force of Mr. Joh. Mayer's observation** to the effect that the Pieler lamp is not, properly speaking, a safety-lamp at all: so long as the large size is maintained it cannot be used in presence of considerable quantities of fire-damp—for in such cases it is liable to passing through or blowing through.

The so-called detector, devised by Mr. W. E. Garforth and perfected by Mr. Lechien,†† has received much praise as being a further practical development of

* "On the Detection of Fire-damp," etc., *op. jam. cit.*

† *Appendices*, vol. iii., page 173.

‡ *Op. et loc. supra cit.*

§ Mr. Fr. Pieler, *Simple Methods of Testing the Air of Mines*, Aix-la-Chapelle, 1883.

|| *Appendices*, vol. I., pages 129-133; vol. iii., pages 167-173; vol. iv., pages 81-84.

** "Utilization of the Pieler Lamp for the detection of Fire-damp," *Oesterr. Zeitschr. f. Berg- u. Huttenwesen*, 1887, No. 9.

†† *Comptes-rendus de la Société de l'Industrie Minérale*, March, 1886; *Glückauf*, 1885, No. 27; *Appendices* vol. iii., page 95; *Bulletin de la Société de l'Encouragement*, etc., 1886, page 229; *Dingler's Pol. Journal*, vol. cclxi. page 476; *Berg- u. Huttenmännische Zeitung*, 1887, No. 1.

the safety-lamp in the direction of its utilization for the detection of fire-damp. It consists essentially of a small rubber ball, by means of which samples of the atmosphere are obtained from cavities and other localities whose direct examination with a safety-lamp may be difficult, not to say dangerous. By screwing this ball on to a pipe in the base of the lamp, and then squeezing the ball, any and every sample may be, either at the spot where obtained or at any other convenient place, led up to the lamp-flame and there tested. The ordinary process of testing is thus subdivided into two distinct processes:—(1) The taking of the sample at the dangerous point, and (2) the actual testing at any locality that may be selected as being free from danger. In view of the simplicity of the method involved, this apparatus is likely to render, at all events, some service in many cases; more especially since the improvements effected by Mr. Lechien (they consist in making the ball close hermetically, and in introducing the gas sample into the interior of the lamp by means of an annular pipe which is slipped from above around the lower portion of the wire-gauze) have disposed of the objections which would certainly be advanced against the perforation of a new opening, needing protection by wire-gauze, in the base of the lamp.

100.—*Regular Examinations of the Workings for Fire-damp.*—The need for timely precautionary measures in the presence of fire-damp entails persistent and unwearied watchfulness, as to the atmospheric condition of the underground working-places. Thus it is, that in the mining regulations of almost every country, we find in the forefront the clause providing that all portions of a pit where fire-damp is known to occur or where its occurrence may be expected, are to be examined daily with the safety-lamp before the hewers, etc., go down the pit, by reliable persons to whom this task is especially entrusted (under-viewers, deputy-overmen). Indeed, the British Royal Commission on Accidents in Mines go a step farther in their *Final Report*,* recommending that the examination or search be conducted with the help of indicators permitting of the detection of so small a proportion as 1 per cent. of inflammable gas in the atmosphere. We must applaud this recommendation when we bear in mind the latest experimental results showing how dangerous are even small quantities of fire-damp in the presence of coal-dust, and we think that in testing the air of workings for such gases, the obligatory use of the Pieler lamp, in addition to that of ordinary safety-lamps, might well be proposed.†

Besides the general examination of the state of the atmosphere in the pit, it is almost everywhere the rule—and very properly, as we think—to prescribe that a regular special examination of each working-place be conducted by one of the men who are to work there (underviewer, deputy-overman, fireman) on each occasion before the resumption of work. On the person who undertakes this task lies more especially the obligation to repeat the test from time to time in the course of the shift. To him also is allotted the duty, as a rule, of testing the atmosphere previous to the firing of blasting-shots.

The Commission are of opinion that, as to the detailed regulations regarding the proper examination of pit-workings for fire-damp, the purpose in view will be best fulfilled by including them in the special working regulations (regulations for the safety of mines) which are drawn up for every fiery mine by the mining authorities, and this has been hitherto the practice in most colliery districts of the kingdom of Prussia.

* Page 117.

† The obligatory use of the Pieler lamp has been enforced in the coal-fields of Austrian Silesia and Moravia by a decree issued from the Imperial and Royal Ministry of Mines at Vienna on June 28th, 1886. As a matter of fact, in many Prussian coal-mines the lamp has long been used for the purpose above referred to—even where there are no official regulations to that effect.

101.—*Chemical Analysis of the Atmosphere of Mines.*—The determination by exact chemical analysis of the proportion of fire-damp present* is, on account of its necessarily elaborate character, hardly applicable to ordinary mining practice. But the numerous analyses carried out by Dr. Schondorff at the instance of the Commission have demonstrated (comp. par. No. 68 of this Report) that it is at any rate important, for the purpose of exercising proper control over the ventilation of the mine, to test the main return air-currents and even some of the chief tributary currents for the quantities of inflammable gas and carbon dioxide carried along with them. For such tests an abridged form of analysis is amply sufficient, as for example that made by means of Dr. Schondorff's much improved form of Mr. Coquillion's grisoumeter† (the principle of which is based on the combustion of the gas by an incandescent palladium or platinum spiral); or that made with Mr. Cl. Winkler's apparatus: ‡ in this case the gas is burnt by means of incandescent copper oxide, and the carbon dioxide which is formed is titrated with baryta water; or, finally, Mr. Pieler's system§ of simply leading the gaseous mixture under analysis through a hydrogen flame.

For the collection of samples of air with a view to chemical analysis, Dr. Schondorff|| has devised special test tubes with the handling of which any mining official can easily familiarize himself. The tubes not only allow of the collection of samples at any point that may be selected within the mine, but may be carried about or kept for an indefinite period of time without injury.

II.—MECHANICAL OR CHEMICAL ELIMINATION OF THE GASES WHICH FORM FIRE-DAMP.

102.—*Compression [or forcing back] of the Gases.*—More than once in earlier days it was proposed, by means of so-called "positive ventilation," that is, by forcing air into the mine, to prevent altogether the exudation of gases from the face of the coal.** Recently this proposal has been revived by Dr. Werner Siemens,†† and in doing so, he has expressed the opinion that the excess of pressure necessary for the purpose need be but a small one, taking into account the effect of the fluctuations of the barometer. But we think that Dr. Siemens' opinion must be characterized as absolutely erroneous, for, as a matter of fact, the pressure with which fire-damp issues from freshly hewn surfaces of coal or from blowers amounts as a rule to a good many atmospheres (comp. pars. Nos. 48 and 66 of this Report). An effective forcing back of the gases could, therefore, be accomplished only at such an atmospheric pressure as would be impracticable for any length of time in coal-workings in full development, without reckoning even that systematic working would be probably thereby rendered impossible. Moreover, it would inevitably happen that at every temporary slackening of the [artificially applied] pressure, outbursts of gas of more

* Dr. Schondorff, "Examination of the Return Air-currents of the Saar Collieries," *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxiv., B., page 73, et seq.; *id. auctor, Appendices*, vol. I., pages 24-30; *id. auctor*, "The Apparatus in the Laboratory of the Prussian Fire-damp Commission," *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxv., B., page 59, et seq.

† Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig. pages 177-179; see also *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxx., B., page 251, and vol. xxxi., B., pages 59-60.

‡ "Chemical Examination of the Return Air-currents in various Collieries in Saxony, and the results thereby obtained," *Jahrb. f. d. Berg- u. Hüttenwesen im Königr. Sachsen*, 1893, pages 65-84.

§ *Simple Methods of Testing the Air of Mines*, Aix-la-Chapelle, 1883.

|| *Appendices*, vol. i., pages 38-40.

** Compare Mr. Habets, "Means of Preventing Fire-damp Explosions and Averting their Hurtful Effects," *Revue Univers. des Mines*, II., L., page 79, et seq. (*Glückauf*, 1876, No. 5, et seq.); also Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig. page 122.

†† Lecture at the May meeting (1890) of the Electrotechnical Association at Berlin, *Zeitschr. des Elektrotechn. Vereins*, 1890, page 191, et seq.

or less magnitude would ensue, bringing in their train a whole crop of perils. Yet further objections to the application of so great an atmospheric pressure arise from the necessity which it would entail of some elaborate system for leading off the air fouled by the abstraction of oxygen and the formation of carbon dioxide,* and from the enhanced risk of fires in the pit by the spontaneous combustion of coal.

103.—*Exhaustion of the Gases.*—Just as difficult in practice as the compression of the gases is the reverse method so often proposed by outsiders, namely, by utilization of decreased pressure to exhaust the fire-damp, and more especially each time before the miners go down the pit, to have it regularly pumped free of gas. Mr. Joh. Schnablegger† believes that coal-seams can be cleared of gas in the following manner:—Two or three times in the week while the miners are above bank, steam is led into the workings by means of a special system of pipes, and in the act of condensation it is supposed to suck the gases out of the surfaces and joints of the coal; the complete elimination of the gases is then effected by working the ordinary ventilator at a still higher speed than usual. Even if one admitted the practicability of such methods, they can never be substituted for a regular system of ventilation; and if the ventilation of a pit is good, they are, to say the least, superfluous.

Better results may be expected from the more far-reaching device of utilizing the low specific gravity of the inflammable gases to capture them (if possible yet unmixed) immediately on their exudation and to lead them off, all by special apparatus totally independent of the ventilation system. Mr. Minary‡ holds that for this purpose a system of porous earthenware pipes is well suited, which would take up the pit-gas by endosmosis, and in connexion with two ventilators (one acting by suction, the other by compression), situated above bank, would lead the gas away. Another proposal of Mr. Minary's is to lead the gases through conduits running along the roof of the galleries into certain spaces set apart as catchment or collecting-drifts (rise-drifts), and thence to bring them to bank by means of pipes. Conceived much on the same plan is Mr. Wodiczka's safety-ventilation,§ wherein, besides the ordinary ventilation ways, an extensive network of pipes for capturing the gases, with numerous suction-valves, is spread throughout the pit up to the working-face: it is supposed to suck in the gas with the greatest rapidity attainable. Finally, Mr. Fauck|| with the same purpose in view, proposes, besides suction-pipes, the boring (from bank down to the highest-placed levels) of special airways or air-shafts.

It must be admitted that a portion of the pit-gas, particularly when it is evolved in large quantities, can be got rid of in the manner above suggested. Indeed it has been the practice for many years past (compare par. No. 66 of this Report) to take off the gas from blowers by a similar, though, it is true, far simpler method. Meanwhile, the assumption which lies at the root of all these proposals, namely, that the exuding gas remains for a considerable time unmixed, floating or swimming, so to say [in the atmosphere], will hardly hold good—least of all when the exudation occurs during the working shift. Therefore, in applying the method of suction, it should be borne in mind that it is gas which is more or less extensively diluted which has to be dealt with. And then the mere installation of

* Compare Mr. Pieler, *Wochenschrift des Vereins Deutsch. Ing.* for 1880, No. 35; also Dr. Serio, *Treatise on Mining*, 4th edition (1884), vol. II., page 311; and Mr. Gurlt, "On Ventilation," *Zeitschr. des Vereins Deutsch. Ing.* for 1884, No. 40.

† "Contributions to the Minimizing of the Risks which arise from the Occurrence of Fire-damp," *Berg- u. Hüttenmännische Zeitung*, 1885, Nos. 30 and 31.

‡ Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig. pages 117-118.

§ Mr. Fr. Wodiczka, *Safety Ventilation, a System of Double Ventilation for Fiery Mines, for Averting Fire-damp Explosions*, Leipzig, 1885; see also *Kompass*, 1887, No. 4, for Mr. Raue's proposals, which are based on similar principles.

|| Mr. Alb. Fauck, "Ventilation of Mines," *Berg- u. Hüttenmännische Zeitung*, 1886, No. 40.

the elaborate suction-apparatus is a matter of no small difficulty, and the necessity of keeping it thoroughly air-tight entails constant, scrupulous vigilance. In addition to this apparatus there must be, as a matter of course in all cases, a well-ordered system of ventilation in the mine; and it comes to this, that the suction-apparatus forms in reality merely a kind of duplicate ventilation system. True, that if the latter be well planned and carried out the mine will be worked, as a consequence, under conditions of enhanced security.*

104.—Combustion of the Gases.—In certain colliery districts, particularly in the kingdom of Saxony, it has until recently been a frequent practice to make use of the so-called "perpetual lamps" or "consuming lamps" for the purpose of getting rid of the pit-gas by means of combustion. Placed in the roof in "bells" at a great many points in the mine and kept continuously burning, these lamps are supposed to consume the gas almost concurrently with its evolution. However harmless such arrangements may be when gas is evolved only in small quantities, they are nevertheless attended with this very serious risk, that if by chance there take place at any time a superabundant evolution of gas an explosion is certain to ensue—even if the lamp-flame be isolated by means of wire-gauze (as Mr. Günther proposed). On that ground, if on no other, the method must therefore be rejected as a bad one.† Moreover, certain experiments conducted by the French Fire-damp Commission have shown that an ordinary pit-lamp, in an atmosphere containing 5 per cent. of methane, in no case consumes more than 18 litres (0.630 cubic feet) of gas per hour, and that consequently the practical efficiency of the perpetual lamp may be regarded as sensibly equivalent to zero.‡

Of equally insignificant value from the practical point of view is the Körner fire-damp consumer.§ This apparatus depends on the combustion of hydrocarbon gases by films of platinum and palladium, which are wrapped round asbestos capsules and maintained in a state of incandescence by means of a ligroïne lamp. Several experiments were made with this apparatus, in rise-drifts known to contain fire-damp, in collieries in the Aix-la-Chapelle and Saarbrück coal districts,|| and, apart from the fact that the apparatus does not work at all in mixtures rich in gas, i.e., containing 12 per cent. and more of methane, it is shown even after long burning to scarcely bring about any marked diminution of the proportion of dangerous gases present in the atmosphere of the mine, while, on the other hand, its combustion-products very markedly deteriorate that atmosphere.

Nor is it an advisable practice to ignite blowers and allow them to go on burning, inasmuch as it entails indirectly the risk of an explosion from the intervention of such external circumstances as vibration of the air (caused by a blasting-shot or by a sudden fall of the roof). The flame being easily extinguished by vibration,

* One member of the Commission, Mr. Hilt, has very recently conducted experiments on gas-suction on a large scale in a colliery managed by him near Aix-la-Chapelle. One point kept in view in these experiments was the suitable utilization of the gases thus drawn off from the pit. The results are extremely satisfactory, placing beyond doubt the practicability of the process, which promises to be as successful from the economic as it is from the engineering standpoint. Even with the present incomplete, purely temporary, arrangements it has been found possible to keep such working-places as are closed off for experiment continuously and perfectly free from gas; and an overwhelmingly large proportion of the gas that usually issues from the mine by the main return air-current, is drawn off through the special conduits (as mixtures containing from 6 to 10 per cent. of methane) and is made use of above bank.

† Compare Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig. pages 118-120; Mr. Menzel, "Review of the Labours of the Commission appointed to Revise the Mining Regulations in Force in Saxony," *Jahrb. f. d. Berg- u. Hüttenwesen im Königr. Sachsen*, 1886, page 8.

‡ Messrs. Mallard and Le Chatelier, *Final Report of the French Fire-damp Commission*, German translation, page 296.

§ "Apparatus for the Combustion of Fire-damp," by Mr. Guido Körner of Freiberg, German Imperial Patents, Nos. 6179, 7469, 11212; see Dr. Siro, *Treatise on Mining*, 4th edition, 1884, vol. II., page 309.

|| *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxx., B. pages 252-253.

large accumulations of gas form at those very points which one imagines are absolutely secure from fire-damp. A far more appropriate method of rendering such blower-gases harmless is to draw them off in special tubes directly into the return air-current, beneath the ventilating-furnace, etc. (compare par. No. 66 of this Report).

A much more dangerous system than that of combustion by perpetual lamps is embodied in the proposals made by several persons (among others, by Dr. Werner Siemens), proposals in substance the same but in form multifarious, to get rid of the fire-damp in the pit by explosion with the electric spark*—this to be done, either as a regular practice every day before the miners go down the pit, or continuously according as the dangerous gases form and accumulate. It is hardly necessary to point out that such methods, which positively remind one of the barbarous old-time "penitent"† system, must be rejected in the most determined manner. Their effect would be to make that very catastrophe against which our most strenuous efforts should be directed—an explosion with all its untold consequences—an ever-recurring incident in the working of mines.

105.—*Other Means of Chemically Decomposing the Gases.*—On account of the small chemical affinity of fire-damp for other substances, the attempt to discover some other method, practically applicable in mining, than oxidation (or combustion) for the removal of the gas has not been so far attended with success. The solubility of the gas in water is so insignificant that it need hardly be taken into account. And as to the proposed decomposition by means of calcium chloride, it has been shown by experiment to be impracticable; besides, the use of that compound, like the use of chlorine gas, is manifestly inadvisable in mines on account of the injurious effects on health of hydrochloric acid and of chlorine.‡

III.—FIRE-DAMP RENDERED INNOCUOUS BY MECHANICAL DILUTION.

106.—In professional circles in every country, the conviction has been steadily gaining ground that the most efficacious method of making fire-damp harmless consists simply in diluting the gas by means of atmospheric air and leading off continuously the dilute gaseous mixture. This purpose will evidently be best fulfilled, and most easily fulfilled, by sending through the entire workings an uninterrupted current of fresh air. Wherefore the efforts which are directed to the minimizing of the danger attending the occurrence of fire-damp are seen to be intimately bound up with the aims which have inspired every system of mining ventilation from the early days onwards. The utmost possible perfection of ventilation is then one of the chief tasks which we must set ourselves in the battle with fire-damp—indeed, it may perhaps be said that it is on this point that the whole battle should be mainly fought.

The preliminary condition of good ventilation of fiery mines is a well-considered arrangement (plan) of the workings, devised so as to give every possible facility to the circulation of air-currents and to the drawing-off of the gases. Before, therefore, considering in the subsequent pages the ventilation of mines, we now propose to

* Dr. Serlo, *Treatise on Mining*, 4th edition, 1884, vol. ii., pages 309-310; Dr. W. Siemens, "Electro-technical Preventives against Fire-damp," *Zeitschr. d. Elektrotechn. Ver.*, 1880, page 191; Mr. Pieler, *Wochenschrift des Vereins Deutsch. Ing.*, 1890, No. 35.

† The deliberate ignition of fire-damp by a workman sent down the pit as pioneer (fireman, *canonnier*, scapegoat) was customary in the olden days in English, French, and Belgian collieries. See Mr. Habets, "Means of Preventing Fire-damp Explosions," etc., *loc. cit.*; also Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig. page 116.

‡ Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig. pages 15-17, 121-122; Dr. Serlo, *Treatise on Mining*, 4th edition, 1884, vol. ii., pages 308-309.

discuss such particular points in connexion therewith as should be taken into account in the installation of a colliery, and especially in the opening-up, fore-winning and working of the seams in fiery mines.

1.—*General Arrangement of the Workings.—Opening-up of the Seams, Fore-winning, and Working.*

107.—*Double-shaft System.*—The air-current which performs the office of ventilation has to be drawn through the workings in a particular direction; it follows, of course, that these must communicate freely with the surface by means of two openings. This requirement is easily complied with in tunnel-workings, and in the upper levels of those deep-mine workings whose seams come directly to the day; but it is not so easy a matter in very deep workings, and particularly in those which underlie enormous thicknesses of (perhaps) water-bearing strata of more recent age—this is the case, for instance, in the northernmost districts of the Lower Rhenish Westphalian coal-field. In order to avoid what is in such districts the prohibitive expense of putting down a second shaft, engineers have deemed it possible to fulfil the requirement of two openings at the surface by dividing the single shaft by an air-tight partition. In this way, a separate air-compartment (upcast) is set up, by means of which the air-current which has gone down the main portion of the shaft (forming the downcast), after it has traversed the workings is drawn up to the day again.*

One may admit that a colliery, of moderate extent and working under favourable conditions, can in this manner be provided with a supply of fresh air sufficient for ordinary purposes of safety. On the other hand, experience has proved that, for such a wide extent of workings as is customary in a deep mine, the single-shaft system, partly because of the difficulty of keeping the partition air-tight, partly because of the small sectional area of the upcast compartment, cannot be trusted to provide a sufficient amount of ventilation for all the working-places. The dangers arising from this insufficiency would of themselves warrant us in deprecating the application of the single-shaft system to large collieries, at least as a permanent arrangement. But there are further reasons—based on the broader ground of general safety—which make the provision of at least two outlets for deep mine workings a matter of commanding necessity.

Proceeding from these considerations, the Commission, in the same manner as the French Commission before them,† have felt impelled to express themselves, as a matter of principle, in favour of the strict enforcement of a method of ventilation based on the double-shaft system, and in the following terms (Art. 2 of the “Principles”) :—

“In all fiery mines, there must be, at the very least, two outlets at the surface, separated from one another by a sufficiently solid wall of rock or stone. Of these two openings, one should serve as a downcast, and the other as an upcast airway.”

“Temporary exceptions to this rule are nevertheless permissible.”

The shortest way, the way attended with the fewest obstacles, and therefore the most efficacious, in which the air-current can be drawn through the workings is to have the two shafts so arranged in regard to their distance one from the other, that they approximately coincide with the respective boundaries (along the dip) of the area worked. The air-current is then enabled to traverse the workings in a uniform generally straight direction, with very little “doubling back” (so called “diagonal”

* Compare *Appendices*, vol. ii., page 134, *et seq.*

† *Principles to be Consulted in Working Fiery Mines*, Paris, 1881, sec. 1.

ventilation-system of Mr. Murgue).^{*} This arrangement of the shafts is the rule, for instance, in most of the Saarbrück collieries. There, either the downcast shaft is situated at one extremity, and the upcast at the other extremity of the area of the particular district (winning); or, supposing that the main downcast shaft is in the centre of the area worked, there is an upcast ventilating-shaft at each of the two [extreme] boundaries. In the latter case, the downcast main current is subdivided into two currents of opposite direction.[†]

Less praiseworthy, from the point of view of good ventilation, is the system of twin-shafts, much favoured in many coal-fields in the more recent deep workings. It is true that in other respects the system offers many advantages; but, as it involves the immediate proximity of the upcast to the downcast shaft, the air-currents are after all brought back to their point of departure in almost exactly the same manner as in the single-shaft system. Thus, not only is the distance to be traversed by the air-currents doubled, whereby a proportionate increase in the loss [or waste] of air is brought about, but also, in the event of an explosion, the difficulty and the delay which attend the re-establishment of a properly regulated air-draught may be enormously enhanced. On the other hand, one must admit that the twin-shaft arrangement is far superior to diagonal ventilation, because by the former system it is easy to secure almost immediately air-communication (intersection) between the two shafts, and consequently a perfectly tight air-current at each new level as it is opened up, and to maintain the same during the fore-winning of the entire area [of the workings]. By the latter system, the two shafts being situated at some considerable distance from each other, the desired condition of affairs is only attained after a great deal of labour (directed to the provision of proper intersections), and labour which is often conducted under most unfavourable circumstances as regards ventilation.[‡] Nor with a centrally situated downcast and upcast shaft, does the duplication of the split currents in the main cross-croft and the diminution of the "maintenance duration" of the main airways appear altogether unprofitable.

108.—*The Formation of Levels.*§—The more or less contorted stratification of the rocks in nearly all the coal-basins of Prussia, together with the generally concomitant occurrence of a large number of workable seams, has almost universally led mining engineers in that country to divide the coal-field which is to be worked into separate sections by horizontal levels, driven at fixed intervals one below the other, whence the working of the coal from the various seams ensues in a given order. From the standpoint of ventilation, and chiefly therefore in fiery mines, this method of opening up the levels with cross-crofts tapping the seams, offers the very essential advantage (compared with the system which prevails in England of working away direct each single seam) that the air-current can be more strictly regulated. And, in particular, each level may be said to possess in the level worked immediately above it, a sort of air-drift which takes the foul air from the lower level and leads it to the surface without further inconvenience or danger to the men at work in the pit.

^{*} Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig. page 82.

[†] Mr. Nasse, "Technical Methods of Working the Royal Collieries at Saarbrück," *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxiii., B., pages 284-285.

[‡] Mr. Hoernecke, "On Precautionary Measures against Fire-damp, etc.," *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxi., B., page 321; *Final Report of the British Royal Commission on Accidents in Mines*, page 12.

[§] Dr. Lottner, "On the Principles to be Observed in Working Coal-seams in Westphalia, with a Critical Examination of the Methods of Working adopted in Belgium, France, and England," *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. vii., B., pages 261, et seq.; Mr. Hoernecke, *op. supra cit.*, *ibid.*, vol. xxxi., B., pages 307-710.

But if the system of levels is to afford the necessary security in fiery mines, it and the coal-workings connected therewith must absolutely proceed from above downwards. For instance, if a lower level was driven as a preliminary, not only would mining operations there be attended (as a consequence) by a more abundant evolution of inflammable gas, but the driving of the next higher level would be rendered more dangerous because a large portion of the fire-damp continuously evolved from the old lower level would naturally stream up into this new one—whereas in the reverse case, the gases can be always drawn off from the older workings without in any way interfering with ordinary mining operations. As further essentials, may be mentioned, the advisability of avoiding too great intervals between levels, or, in other words, too great a height of workings; also the need for the greatest possible regularity [of plan] and concentration of the workings, for it is only by this means, under ordinary circumstances, that a sufficiently cool, rapid, and powerful air-current can be made available for every traversable part of the mine.

109.—*Opening out of the Seams.*—At each new level, the necessary opening out of the individual seams is accomplished by means of cross-cruts and level drifts. As in these cases it is almost always virgin ground that is being cut through, the pioneering workmen have generally to contend with a fierce evolution of fire-damp. But it is just this partial escape of the dangerous gases which makes matters comparatively easy for the workmen subsequently engaged in fore-winning and regular working (compare pars. No. 67 and 68 of this Report).

It is, therefore, important that the preliminary opening up should be accomplished early and according to a well-considered plan, so that the area of the winning may be, so far as possible, cleared of gases before the operations of fore-winning and regular working are started. For this reason it will be generally found necessary to deviate from the accepted principle of concentration of the workings, inasmuch as two or even three levels will have to be driven simultaneously. Of these the lowest would be in the new ground or fore-winning, the next above in course of working or fore-winning-and-working, and the uppermost on the point of being abandoned. Naturally, in the course of these operations, care will have to be taken (by means of an adequate ventilation-system) that the gas-fouled air-currents from the lower levels do not traverse the working portions of the upper levels.

If the evolution of gas in the newly opened-up drifts were extremely rapid, it would be a wise plan to suspend operations for a time, and to provisionally allow these drifts to empty themselves, as it were, of gas. In certain cases it would even be advisable to completely suspend operations in particular places, and attempt to get rid of the gas by other means. Thus, for instance, in the pits of the Wurm district, the course has been lately adopted of driving special headways up to the "closed saddles" for getting rid of the gas, and leaving these open for a considerable time before the fore-winning of the area is begun.* In England, in cases where the country-rock is largely permeated with gas, good results are obtained by piercing boreholes at regular intervals in the hanging-wall or footwall of the seams within the opening-up drifts—whereby the gases are led off, and the thrust of the roof or creeping of the floor, as well as a sudden outburst of gas, is avoided.† Actual blowers with continuous evolution of gas are best dealt with as near as possible to their point of issue, and the gas should be led off by means of a special range of pipes.

* "Ventilation of the *Gemeinschaft colliery*," *Zeitschr. f. d. Berg-, Hatten-u. Salinen-Wesen in Preuss. Staat*, vol. xxxi., B., page 78.

† Mr. Kreisicher, "Preliminary Report of the British Royal Commission on Accidents in Mines," *op. cit.*, pages 13-14, 29-30.

In consideration of the fact that the cross-cruts and level-drifts communicating with the shafts should convey the fresh air-current to all the working-places on their own level, and later on also help to lead off the gas-fouled air from the next lower level, one preliminary condition above all must be observed, that is, their amply sufficient sectional area. The neglect of this principle makes itself of necessity the more severely felt the deeper the workings are pushed; and it is to this neglect that we must largely attribute the generally unsatisfactory condition of ventilation noted by the Local Mining Section of Dortmund on their tour of inspection through certain Westphalian collieries. We have therefore no hesitation in expressing our absolute concurrence with the following conclusions, laid down in the Final Report of that section * :—

"The endeavour to provide Westphalian collieries with an adequately powerful system of ventilation is in many cases barred by this difficulty—that the cross-cruts of such upper level-drifts as were constructed many years ago, and these must now be used as airways, are of too small sectional area. Similar difficulties arise in several collieries from the often insufficient sectional area (certainly inadequate considering the present development of the workings) of the air-compartments in shafts."

"If it is only by degrees that we may hope to overcome these obstacles, that is, by gradually doing away with the old level-drifts and cutting new ones, or reconstructing the shafts, one rule at least may be urgently set forth as indispensable in the case of newly opened level-drifts and new shafts—namely, that the main airways and air-compartments should have a minimum sectional area of 3 square metres (32.29 square feet)."

We should add to the above the suggestion, that in all the larger deep-working collieries it would be advisable from the very start to line the main exploration (or fore-winning) galleries with masonry or iron girders, with a view to their subsequent utilization for a long period of time as airways; and to give them at the same time the rounded-off sectional shape which is most favourable to the unimpaired transmission of the air-current.

110.—*Fore-winning and Working.* †—If by the term fore-winning we understand (and this appears to be the most reasonable definition) merely such operations as are necessary to prepare the section of coal-seam newly laid open by the level-drift for the subsequent actual winning of the coal, then the mode of fore-winning is always more or less dependent on the selected method of working. A complete investigation of the many points which have an important bearing on the question lies beyond the scope of this report, and we propose, in the following considerations, to deal only with fore-winning and working in so far as they touch the problem of ventilation.

The methods of working applicable to coal-seams are divisible into two principal groups. In the one, the pillar-and-stall system, fore-winning and actual working

* *Appendices*, vol. II., pages 228-229 (Conclusions, Nos. 5 and 6).

† Dr. Lottner, "On the Principles to be Observed in Working Coal-seams in Westphalia," etc., *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. VII., B., page 281, et seq.; Mr. Gurit, *The Prevention of Fire-damp Explosions in Collieries*, Bonn, 1880; Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig., pages 133-144; Dr. Kreischer, "Preliminary Report of the British Royal Commission on Accidents in Mines," *op. jam. cit.*, pages 9-10; Mr. Hoernecke, "On Precautionary Measures against Fire-damp," etc., *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. XXXI., B., pages 310, 325-331; Mr. Simmersbach, "Description and Criticism of the Methods of Exploration, Fore-winning, and Ventilation in Use in German Mining," etc., *ibid.*, page 332, et seq.; Mr. Gurit, "On the Working of Fiery Coal-seams," *Zweiter Allgemeiner Deutscher Bergmannstag* (German Mining Congress), Dresden, 1883; *Appendices* to this Report, vol. II., pages 108-110; Mr. Menzel, "Review of the Labours of the Commission appointed to Revise the Mining Regulations in Force in Saxony," *Jahrb. f. d. Berg- u. Hüttenwesen im Königr. Sachsen*, 1886, pages 16-17.

are two separate, independent operations: first the boardways or stalls are cut, and then follows the removal of the thereby separated strips of the seam or pillars. In the other, the chief representatives of which are the longwall system and overhand stoping, there is no need for any preliminary division of the seam into strips; in fact there is scarcely any fore-winning needed; and the winning of the coal can go on in one and the same operation as, and almost simultaneously with, the opening-up or working of the seam. An indispensable corollary of the utilization of this method is a thorough, complete stowing of the goaves to which it gives rise.

In Prussian coal-mining, the character of the seams, and in particular the very general want of sufficient waste-rock for stowing purposes, has had for a consequence the almost universal predominance hitherto of the pillar-and-stall system. Longwall prevails only in a few districts with thin seams, and overhand stoping has been exclusively confined to the steeply-inclined seams of the Wurm basin. However, in view of the increasing risk of fire-damp the deeper the workings go, engineers have lately begun, and very properly, to allow the question of ventilation to influence more largely the choice of the method of working.

Compared with longwall and overhand stoping, pillar-and-stall working has this great disadvantage, that it does not (like the former) allow of that concentration of the workings which is a prime necessity for the maintenance of a powerful air-current. Add to this the more serious drawback that, in ordinary circumstances in pillar-and-stall working (at least when complete stowing is not carried on up to the working-face), the working-places have to depend for their ventilation simply on the diffusion of the air-current which passes through the next preceding holing; whereas in longwall working and overhand stoping the air-current traverses every working-place in unimpaired strength. Both disadvantages are the more keenly felt, according as the length of the airways of each separate district adds up to a more considerable total, and according as they must be kept open for a longer period of time; what with the many sharp bends to which the air-current is thus subjected, the bends and turns (variability) of the direction of the galleries, and the difficulty of keeping the worked-out-galleries air-tight, etc., the never-failing consequence is an enormous waste or loss of air.

On the other hand, pillar-and-stall work, with its subdivision of the operations into fore-winning and actual working, has in very fiery seams at least this advantage that in the process of fore-winning a comparatively large surface of coal-seam is laid bare, and thereby an even, continuous evolution of gas is promoted, so that the subsequent operations of actual mining are, as a rule, but little impeded by the presence of fire-damp. Having, on the contrary, in longwall and overhand stoping constantly to deal with freshly broken surfaces, one there meets continually with a full evolution of gas (compare par. No. 67 of this Report). But here again, such advantages as pillar-and-stall work afford are (in part at least) counterbalanced by the possible danger to the workings still in progress arising from gases, which either have accumulated in the worked-out spaces [goaf] or have been newly evolved through sudden falls of roof.

We therefore conclude that, as a general rule in fiery mines, longwall and overhand stoping are to be recommended in preference to pillar-and-stall work. Where, however, the last-named method is necessarily adhered to, having regard to the particular thickness of the seams, the lie of the strata, and other local conditions, every effort should be exerted in the direction of minimizing the defects above enumerated by means of appropriate modifications of the ordinary mode of working. The most potent factor in this sense is a perfect (or as nearly perfect as

may be) system of stowing: a system which shall, on the one hand, avoid all useless splitting of the air-current, while on the other, it allows of the transmission of the fresh air to the immediate vicinity of the working-face. The latter result will be much facilitated by the diminution of the intervals between each individual holing, by the keeping open of a so-called air-course (airway) in the stowing, and by the provision of brattice-cloth, etc.; the former result, by careful, close packing of the stowing, and by hermetically sealing up such holings as need not be kept open for purposes of ventilation (compare Art. 10 of the "Principles"). Other means of favourably modifying the ventilation in pillar-and-stall work will in many cases be found in the working of larger sizes of pillars, in the longwall working of the pillars themselves, and in the reduction of the length of the working district.

In what direction the workings should be pushed forward, whether from the downcast shaft towards the boundary of the royalties or in the reverse direction, appears to be of little consequence so far as ventilation is concerned. Provided that in a particular direction only one district (self-acting plane area) limited by safety-pillars, be worked at a time; or provided that, two such districts being worked at one and the same time, each be ventilated by an absolutely separate air-current. Where these provisions are not enforced, then the particular direction in which the workings are pushed forward will be more or less advantageous than any other direction, according to the distance between the downcast and the upcast shafts. If the two shafts be remote from one another, it will be best to carry the workings from the downcast shaft outwards to the royalty-boundary, because then the return airways will gradually become shorter, and therefore more easily kept open. In the case of twin-shafts, on the other hand, but for the very same reasons, the workings should be carried from the royalty-boundary inwards.

True, that in certain circumstances, the last-mentioned method of working should cease; for, since the fore-winning of the seam along the whole length of the level-drift must then precede the actual winning, an enormous total length of galleries will lie open; and these, if the mine be dry and the coal dusty, form a dangerous area of propagation for such local fire-damp or dust-explosions as may arise: a danger exemplified by the gas explosion which took place on March 17th, 1885, in the Camphausen pit, near Saarbrück. The simultaneous working of several seams on the same level and with the same air-current is advisable only when the seams lie so close to one another that, by means of short cross-cruts, they may be fore-won together and worked together. On the whole, we should prefer to see the seams worked in a definite order, depending on the lie of the strata (as a rule from hanging-wall to footwall) one after another, each particular seam to be worked on the most concentrated method available.

111.—*The Operations of Exploration, Fore-winning, and Working considered.*—We now supplement the general considerations which precede, by a few particular rules, the enforcement of which we regard as important in carrying out such operations as are connected with exploration, fore-winning, and working in fiery mines:—

- 1.—As a general principle, fore-winning and working should not be started in any district before the air-communication has been secured with an upper level (compare Art. 17 of the "Principles").
- 2.—In very fiery seams it will be in most cases advisable to allow a certain interval of time to elapse between the operations of fore-winning and actual working.
- 3.—In exploration work, as well as in fore-winning and in actual working, driving to the rise should be as far as possible avoided. Where it cannot by any means be avoided, the driving should be done only with the help of special ventilation (see Art. 10 of the "Principles").

Air boreholes may [in such cases] be considered an adequate substitute for the ordinary rise-drifts or pillar holings. With rise-shafts the preliminary driving of an air borehole is in all cases advisable.

Where fire-damp is known to occur, working to the rise is to be altogether deprecated.

- 4.—The rise of bords or stalls should in no case exceed 1 in 100 (see Art. 10 of the "Principles").
- 5.—In pillar-and-stall work the hewing of the individual pillars should take place in an order such that the upper pillar (according to the dip of the seam) should be always a little in advance of the next lowest, so that the foul air from the worked-out spaces [goaf] may be drawn away upwards without impeding the working of the lower pillar.
- 6.—The bases of "caldron-bottoms" in the roof of a seam are to be stowed as close as possible.
- 7.—Preliminary boring should be carried on at those working-places which approach goaf, old workings, or such like, where accumulations of fire-damp may be looked for (see Art. 14 of the "Principles").

112.—*Old Workings*.—There are two ways in which the old workings [goaf] of a pit may have an injurious influence on the ventilation of the actual workings. On the one hand, the fresh air is [inevitably] diverted in part into the old workings, and so that part is lost for all useful purposes; on the other, the foul air or foul gases which accumulate in the old working do at times invade the working-places which are in active use. The first-mentioned evil must be combated by means of an appropriate system of conducting the air and of keeping the airways constantly air-tight. Then, as to the prevention of the invasion of the workings by foul air, either the old workings should be carefully dammed off by means of barriers erected within the safety-pillars which mark their limits (but, in order to avoid undue tension of the imprisoned gases, an outlet opening upwards is left); or the old workings should be continuously traversed by a moderate air-current (compare par. No. 69 of this Report, and Art. 14 of the "Principles").

2.—*Ventilation of Mines.*

113.—*Ventilation considered Generally*.—The aim of every system of ventilation of mines is to establish and maintain within all practicable portions of the underground workings such a state of the atmosphere as shall most nearly approach the conditions of the fresh air above bank, and at the very least to prevent the air in the pit from being injurious to the health or perilous to the life of man. This aim is only attainable by the well-planned and continuous transmission of a current of fresh air which shall be strong enough: (1) to replace the air fouled by the breathing of men and horses, by the products of combustion of safety-lamps, by various chemical changes, etc.; (2) to keep the temperature at the working-place within reasonable limits; and (3) to sufficiently dilute and readily lead off the injurious gases which may be evolved.

In fiery mines, the task which the ventilator is called upon to fulfil is further extended, so as to include the neutralization of the danger of fire-damp (compare

* Mr. Pfähler, "Ventilation in the Royal Colliery of Sulzbach-Altenwald, near Saarbrück," *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staat*, vol. xx., B., page 50, *et seq.*; Dr. Schondorff, "Examination of the Return Air-currents of the Saar collieries," *ibid.*, vol. xxiv., B., page 73, *et seq.*; "Rescript of the French Ministry of Public Works, of December 6th, 1872, on the Precautionary Measures to be adopted in Fiery Mines, and notably on the System of Ventilation," *Annales des Mines*, series 7, vol. ii. (Partie Administrative), page 138; there is a German translation by Mr. Koch in the *Zeitschr. f. Bergrecht*, vol. xiv., page 273; Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig., page 69, *et seq.*

par. No. 106 of this Report). But in these cases this extension is of such capital importance as to constitute more or less the crucial point of the whole problem of ventilation. As a consequence, the Commission have in Art. 3 of their "Principles" laid down the following prescription as a kind of fundamental law to be observed in the ventilation of fiery mines:—

"In every fiery mine, a regular system of ventilation must be arranged in such a manner, that accumulations of fire-damp may be rendered practically impossible (under ordinary conditions) in the working-places; and every portion of the mine, at the working-places or in the galleries, shall be at all times in a fit condition for the conduct of mining operations and the traffic of the mine."

In large collieries, it would probably be difficult to comply fully with this regulation by means of a single continuous air-current; and in them it is advisable to divide the workings into several independent ventilation-districts, each of which is supplied by its own separate air-current. Such a division of the mine tends not only to facilitate in a remarkable degree the proper ventilation of the workings, but further affords a most effective safeguard against the undue extension of such fire-damp or coal-dust explosions as may occur.

114.—*Natural and Artificial Ventilation*.*—The circulation of air in mines depends on the necessary assumption that the equilibrium of the mass of air is disturbed in one direction, or in other words, that the air-column in one of the two shafts (which have to be considered in connexion with the air-current) is lighter than the air-column in the other shaft. If these two outlets are at different [surface-] levels, or if the disturbance of equilibrium be simply a result of the difference of temperature between the underground workings and the surface, we then have to deal with a natural air-draught.

Now, however efficient an agent of ventilation this, in certain circumstances, may be its very dependence on the ever-varying surface-temperature deprives it of the essential quality of permanence or stability. Ventilation, exclusively conducted by means of natural air-draught, is therefore at once "put out of court," so far as fiery mines are concerned (see Art. 4 of the "Principles"),† and in connexion with them we have, in fact, chiefly to consider the means of producing an artificial circulation of air.

The artificial production of an air-current traversing the mine is set up, either by suction, which implies rarefaction of the air, through the upcast-outlet while at the downcast-inlet the external atmospheric pressure continually forces fresh air into the mine; or by pressure, which implies compression of the air, at one end, the air which is in the mine being consequently driven out at the other end. We may leave the question open, as to which of these two methods offers the greatest advantages in fiery mines.‡ As a matter of fact, the method of compression of fresh

* Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig., pages 90-93; Mr. Hoernecke, "On Precautionary Measures against Fire-damp," etc., *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxi., B., pages 301-306; Mr. Gurit, "On Ventilation," *Zeitschr. des Vereins Deutsch. Ing.*, 1884, No. 42.

† In this category may be comprised the exclusive use of mere air-chimneys or air-tubes (without furnaces), as these only produce after all a magnified natural air-draught, by increasing the difference of level between the two surface-outlets.

‡ Mr. Menzel, "Method of Working of Suction-conduits and Compression-conduits in Fiery Mines," *Civil-ingenieur*, 1878, page 71; Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig., pages 100-103; Mr. B. Otto, "The Underground Guibal Ventilator in the Alexander Shaft of the Von Arnim Collieries at Plantitz, near Zwickau, together with some Remarks on the Compression Method in the Ventilation of Mines," *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxii., B., page 159, et seq.; Mr. F. Rochelt, "On the Ventilation of Collieries where Explosions are considered probable," *Oesterr. Zeitschr. f. Berg- u. Hüttenwesen*, 1885, Nos. 15, 16, and 21; Mr. Hippmann, *ibid.*, No. 19; Mr. B. Otto, *Fire-damp and no Aim of Providence*, Leipzig, 1886, pages 21-47; Mr. Von Rühl, *Fire-damp*, Vienna, 1886, pages 48-50.

air (positive system) has been adopted to the ventilation of entire collieries in only a very few cases up to the present time. In the coal-mining industry of Prussia, the exhaustion-method of ventilation is almost universally employed.*

The process of exhaustion results either from the heating of the upcast air-column (ventilation-furnaces, etc.), or from the direct mechanical rarefaction of the same. The amount of deficiency of air-pressure (depression or water-gauge) which is sought to be attained at the upcast outlet depends partly on the resistance offered by friction to the free course of the air-current through the mine, and this, varying according to the length, sectional area, and general disposition of the airways, is termed the mechanical temperament of the mine; partly on the quantity of air required [for ventilation purposes]. According to the conditions obtaining in each particular locality, the exhausting power may, or may not, need additional reinforcement in order to overcome the natural draught which may possibly make itself felt in a contrary direction. As a rule, however, the natural draught acts in the same sense as the artificial means of ventilation, and thus really forms an auxiliary to the suction power.†

115.—The Quantity of Air requisite for Ventilation.‡—If the ventilation of a mine be planned so as to fulfil in every respect the aims which it should fulfil, the quantity of fresh air introduced into the pit must be at the very least sufficient to neutralize the worst imaginable fouling of the actual pit-air which can happen in the several working-places in the course of one working shift. In so far as this fouling of the air results from the breathing of men and horses, from the burning of pit lights, and from such shot-firing as may take place, the calculation of the needful quantity of fresh air may be based simply on the greatest number of men and horses present in the pit at one time. But the calculation is far otherwise complicated when other considerations intervene—such as, lowering of the temperature in the pit, dealing with chemical processes like the rotting of timber or the decomposition of pyrites, and more especially the prevention of accumulations of fire-damp. In such cases it would hardly be correct to reckon only the number of workpeople and horses employed as the standard of measurement, and plan the total air-supply in accordance therewith; this method would be erroneous, because the various causes of air-fouling enumerated in the previous sentence depend almost entirely on the very variable local conditions, such as the different character of the seams, the “chemical temperament” of the individual colliery—and yet this is the method of calculation which has been hitherto very largely prescribed in mining regulations.

Starting from the proposition that in fiery mines, as proved by experience, the evolution of dangerous gases far exceeds all other contributory causes of the fouling of the air, the Commission hold that the ventilation of such mines should be made to a certain extent directly dependent on the more or less considerable evolution of gas known to take place there. The experiments conducted by the Commission (compare pars. Nos. 67 and 68 of this Report) have shown that the newly-bared

* The use of compression in separate (or divided) ventilation will be dealt with in another portion of this Report.

† Compare *Appendices*, vol. v., pages 86, 87, 89.

‡ Mr. Pfähler, “Ventilation in the Royal Colliery of Sulzbach-Altenwald, near Saarbrück,” *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xx., B., pages 57-69; Mr. Nonne, “Ventilation in Westphalian Collieries, with especial reference to the Labours of the Commission appointed to enquire into Ventilation,” *ibid.*, vol. xxi., B., page 71; Dr. Schondorff, “Examination of the Return Air-currents of the Saar collieries,” *ibid.*, vol. xxiv., B., pages 80-82, 107-117; Mr. Hoernecke, “On Precautionary Measures against Fire-damp,” etc., *ibid.*, vol. xxxi., B., pages 301-302; Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig., pages 70-76; Mr. B. Otto, *Fire-damp and no Aim of Providence*, Leipzig, 1886, pages 63-69; Mr. Von Kziha, *Fire-damp*, Vienna, 1886, pages 45-47.

surfaces of coal [working-face] give the best means of measuring this evolution—although, taken as a whole, the amount of coal won within a given interval of time would furnish a sufficiently trustworthy basis of calculation, if at the same time the gaseous [methane] and carbonic-acid content of the return air-current be taken into consideration.

According to the views of the Commission, adequate subdivision and conduction of the fresh air-currents being assumed, the highest admissible degree of fouling of the air in the pit would be represented by a gaseous content in the main return air-current of 1·5 per cent. of fire-damp and carbonic acid gas. The quantity of air-supply should therefore be so calculated as to exclude any possibility of this percentage being exceeded. Judging from the ordinary conditions of gas evolution in Prussian collieries, the aim in view would be attained if the fresh air-supply were calculated at between 1 and $1\frac{1}{2}$ cubic metres (35·31 and 52·95 cubic feet) per ton of the average daily coal-output and per minute. A more abundant air-supply would be needed only in specially dangerous fiery mines, or in the event of exceptionally extensive fore-winning operations.

The Commission have further taken into consideration the hitherto customary method of reckoning the air-supply according to the number of workpeople employed, to this extent that they have given their sanction to the rule now pretty universally recognized by the mining profession in Germany—namely, that in all fiery mines the amount of air-supply per minute should be at least 2 cubic metres (70·62 cubic feet per minute) for each person at that time employed in the pit.

And so it is that Art. 5 of the "Principles" drafted by the Commission runs as follows :—

"The volume of fresh air per minute, which should be supplied in a fiery mine, must in each independent ventilation-district amount to 1·5 cubic metres (52·95 cubic feet) per ton of the average daily coal output. If this volume be inadequate to reduce the gaseous content of the return air-current to 1·5 per cent., it must be correspondingly increased. Where, on the other hand, the total percentage of methane and carbon dioxide in that current does not unitedly amount to 1·5, a reduction of the fresh air-supply to 1 cubic metre (35·31 cubic feet) per ton of daily coal output may be regarded as admissible."

"In all cases, however, the volume of fresh air must amount to at least 2 cubic metres (70·62 cubic feet) per head of the maximum number of workmen employed below ground in the course of one shift. In these calculations a horse is reckoned as equivalent to four men."

The investigations regarding the quantities of air entering or issuing from the mine, undertaken by the Commission in the course of their various tours of inspection from 1881 to 1883, both years inclusive,* in conjunction with Dr. Schondorff's chemical examination of return air-currents,† do indeed show that already at that time the above requirements were practically complied with to the fullest extent in the overwhelming majority of the fiery mines that were visited. But it was also demonstrated that not a few collieries needed some considerable improvements in their ventilating appliances.

116.—Means of Producing the Requisite Quantity of Air.—Among the appliances for artificially ventilating the entire workings of a fiery mine must naturally be ranked first of all (subject to the reservations set forth by the Commission, so

* *Appendices*, vol. i., pages 157-163, 179-181; *ibid.*, vol. ii., pages 73-74, 77-78, 92-101, 106-107.

† Dr. Schondorff, "Chemical Investigation of the Fire-damp in Prussian Mines," *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxi., B., pages 435-445, and vol. xxxii., B., pages 509-519.

far as regards Prussian mining industry at any rate*) ventilation-furnaces and mechanical ventilators. Ventilation-chimneys, steam-piping, and steam-jet apparatus respectively are still used here and there; while the introduction of compressed air and the use of air-jet apparatus should be confined to the separate (divided) ventilation of individual working-places or parts of workings (compare para. Nos. 37, 38, and 39 of this Report).

The chimneys of steam-boiler furnaces, if brought into communication with the upcast outlet of the pit, may undoubtedly perform useful service in the way of rendering still more efficient such means of ventilation as are otherwise provided. But it appears to us inadmissible that one should seek to create an air-draught in a fiery mine by the help of such chimneys alone (see Art. 4 of the "Principles"). Their action is too limited, and is too dependent on the changeable firing of the boilers, that is, on the varying steam-consumption of the machinery connected therewith. As a matter of fact, in the Lower Renish Westphalian coal-basin, to which the use of this arrangement has been mainly confined, the boiler-chimneys are now generally regarded as merely an additional resource in case of need.

Of more value for ventilation purposes is the heating of the upcast air-shafts by means of the steam-pipes connected with engines in the pit. The experiments of the Ventilation Sub-committee at the Königs pit near Aix-la-Chapelle, and at the Westfalia pit near Dortmund,† have shown that such steam-pipes (owing to their continuity or constancy of action) can very well be substituted for a small ventilator. It should, however, be borne in mind that the exhaustion (depression or water-gauge) which may be obtained by their means is somewhat limited, and that there are objections to their use from the standpoint of economy and of the practical working of the mine.

The Koerting steam-injector must of course be admitted to be thoroughly efficient, and it has in some few cases been successfully applied in fiery mines. But the wasteful expenditure of steam which it involves appears likely to prevent any great extension of its use for the ventilation of fairly large collieries.

117. —*The Ventilation Furnaces*,‡ still largely used in Prussian coal mines, are open to the weighty objection which on principle applies to the presence of naked light or open fire in fiery mines (compare par. No. 93 of this Report). If in practice this objection is not of such transcendent importance as to justify the universal prohibition of ventilating-furnaces in fiery mines, the following requirements must at least be complied with. Not only, under ordinary circumstances, should all contact between the return air-current and the open flame or the burning gaseous products of combustion rising from the furnace-hearth be avoided, but adequate preventive measures should be taken in view of the possible influence of an explosion taking place in the pit, of the conflagration of a shaft, or any other unusual occurrence which may cause reversal of the air-draught. The Commission are of

* Mr. Hasselacher, "The Collieries of Prussia from the point of view of the Diversity of their Ventilation," *Zeitschr. f. d. Berg-, Hütten-u. Salinen-Wesen im Preuss. Staate*, vol. xxx., B., page 181, et seq.; Mr. Althaus, "Statistics of Ventilation Appliances in the Mines of the Kingdom of Prussia," *Appendices to this Report*, vol. v., pages 1-77.

† *Appendices*, vol. v., pages 89-90, 105.

‡ Mr. Pfähler, "Ventilation in the Royal Colliery of Sulzbach-Altenwald, near Saarbrück," *Zeitschr. f. d. Berg-, Hütten-u. Salinen-Wesen im Preuss. Staate*, vol. xx., B., page 71; Mr. Nonne, "Ventilation in Westphalian Collieries," etc., *ibid.*, vol. xxi., B., pages 59-70; Mr. Hoernecke, "On Precautionary Measures against Fire-damp," etc., *ibid.*, vol. xxxi., B., pages 303-304; Mr. Simmersbach, "Description and Criticism of the Methods of Exploration, Fore-winning, and Ventilation in Use in German Mining," etc., *ibid.*, pages 339-340; Mr. Gurik, "On Ventilation," *Zeitschr. d. Vereins Deutsch. Ing.*, 1884, No. 43; Dr. Kreischer, "Preliminary Report of the British Royal Commission," *op. jam cit.*, page 10; *Final Report of the British Royal Commission on Accidents in Mines*, pages 9, 111; Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig., pages 94-97.

opinion (see Art. 4 of the "Principles") that the use of ventilating-furnaces is only admissible in those cases where there is a perfect supply of fresh air to the furnace, where a safe means of retreat for the furnaceman is provided, and where the possibility of ignition of the pit gases by the furnace gases is absolutely excluded.

With regard to their motive efficiency, ventilating-furnaces are, on the whole, suitable only for such collieries as those where the frictional-resistances do not make a too high depression [water-gauge] necessary. Where the conditions laid down admit of their use, almost any amount of air can be got through the pit by means of them, as experiments in English collieries have shown. From the economic standpoint, however, furnaces appear to be advantageous only when placed underground, and the pit-shafts are deep and dry. If the entire grate-surface be made full use of, and a disproportionately large amount of coal be expended, there results within narrow limits a temporary increase of efficiency: this augmented efficiency is, however, more easily secured by holding in readiness a second fire-grate.

118.—*Mechanical Ventilators** must be regarded as in every respect the safest means of providing ventilation in fiery mines, and as being the appliances which most easily fit in with all the conditions of working of mines. Although their first use in Prussian coal-mining dates only from the year 1856, they seem now to have become in all the coal-fields of the kingdom, at any rate in the larger mines, the principal appliances for ventilation. Of the numerous inventions in this line that have been brought forward, the rotary-pumps and screw-fans have come into practical use only in the form of the Fabry ventilator (and therewith the Kaselowski system); while the piston-machines and the Lemielle ventilator have obtained no footing at all.† Among the centrifugal fans which alone have been introduced within the last twenty years, the slow-running Guibal ventilators (lately much used with the Kley spiral inlet) occupy pre-eminently the first place. Up to near the end of the 'seventies their only rivals worthy of consideration were the quick-running fans of Zimmermann and Rittinger, and the conical fan of Schwarzkopf. Since then, general preference appears to have been accorded to the Pelzer conical fan, also to the quick-running fans of Schiele, Winter, and Wagner; and more recently these have been supplemented by the Moritz and Geisler systems.‡

The ventilators being built on the exhausting-principle, they are as a rule placed above bank.§ But of late years, installations underground has also been much resorted to, as for example with Schiele ventilators in the Rheinpreussen colliery at Homberg-on-the-Rhine (1883) and in the Graf Moltke colliery at Gladbeck (1884).|| and with the Geisler modification of the Rittinger ventilator at the Shamrock pit, near

* See, for literature, footnote to par. 117 (ventilation-furnaces), also the following:—Mr. Devillez, *Ventilation of Mines*, Mons, 1875; Mr. D. Murgue, "On Mechanical Ventilators," *Bull. Soc. Industrie Minérale* series 2, vol. ii., page 445, *et seq.*, vol. iv., page 747, *et seq.*, vol. ix., page 5, *et seq.* (German adaptation by Mr. J. Von Hauer, *On Mine Ventilators*, Leipzig, 1884); "Report of the Commission for Comparison of the various Ventilation Appliances in the Gard Coal-field," *Bull. Soc. Industrie Minérale*, series 2, vol. vii., page 477, *et seq.*; "Report of the Committee on Mechanical Ventilators," *Trans. N. E. Inst. Min. and Mech. Eng.*, vol. xxx. (1881), page 27, *et seq.*; Mr. Joh. Mayer, "Air-measurements and Comparative Observations on Guibal and Rittinger Ventilators," etc., *Oester. Zeitschr. f. Berg- u. Hüttenwesen*, 1880 and 1881; Mr. Pelzer, "Ventilation of Mines," *Glückauf*, 1882, No. 49; Dr. Serlo, *Treatise on Mining*, 4th ed. (1884) vol. ii., pages 368-421; *Appendices*, vol. v.

† It should, however, be mentioned that in the 'fifties an underground ventilating-pump was driven by a water-wheel in the Gewalt pit, near Steele, Westphalia. It was at work for a short time only, and its efficiency was small.

‡ Mr. Althaus, "Statistics of Ventilation Appliances in the Mines of the Kingdom of Prussia," *Appendices*, vol. v., pages 1-6.

§ It is of course understood that we are dealing here only with ventilators which serve to provide air for the entire workings of a mine.

|| *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxii., B., pages 300-302; *ibid.*, vol. xxiii., B., page 242.

Herne (1886).^{*} In such a case the ventilator standing in the return air-drift blows the [foul] air sucked from the workings up into the shaft. This arrangement would seem to be advantageous only where the same shaft is both upcast and downcast: for whilst the air is being blown out both shaft-compartments are practically under the same atmospheric pressure, and thereby is completely avoided the otherwise considerable waste of air which results from any leakage through the shaft-partition (when there is a depression in the upcast compartment).

Although the actual construction of ventilators, viewed from the standpoint of security in the working of mines, comes into question only so far as the provision of a definite quantity of air in the pit by means of the ventilator is assured, the Commission have considered it their duty (taking into account the growing importance of mechanical ventilators) to carry out comparative investigations of the best known inventions—in the course of which investigations full regard has been paid to such points as general mechanical efficiency and economy. With this object a Sub-Committee on ventilators was appointed, and they undertook a searching examination into the various methods of ventilation at that time (April, 1883) in use in Prussian mines, besides many practical investigations and experiments on particular ventilators. For the detailed results of these labours we must, of course, refer the reader to the reports† of that Sub-Committee, but a few of the more important conclusions may be here enumerated as follows:—

- 1.—With the centrifugal ventilator the entry of the air into the compartments formed by the blades of the fan should take place free from jerk or concussion, that is, without any sudden alteration of velocity. The compartments between the blades of the fan must be sufficiently wide for the velocity of the air, even at the highest speed of the ventilator, not to be maintained at a greater average than 10 metres (32·8 feet) per second. The requisite depression (water-gauge) must be attained with the smallest possible diameter of fan.
- 2.—High manometric efficiency in centrifugal ventilators is only attainable by means of diffusers, together with suitable encasing [or hooding] of the fan. Moreover, the frictional-surfaces must be of the smallest possible area, and for this purpose, with the big Guibal fans, instead of using the present arrangement of casing and one chimney or diffuser which gives rise to large friction surfaces, it would be advisable to distribute a number of small diffusers over the periphery of the fan (Kley or Harze system). Such a system also possesses the advantage of doing away with the extremely serious disturbances of the air-draught which so often take place in the diffuser-chimneys of the Guibal type, as a consequence of the action of gusts of wind on the *écusée* chimney.
- 3.—From the point of view both of mechanical efficiency and of economy, the ventilator should be exactly suited to the conditions of the particular pit in which it is placed. Here, the first thing to consider is the size of the ventilator; if this be selected in due proportion to the orifice‡ of the mine and the requisite air-supply, the various systems of Guibal, Pelzer, Schiele, and Winter will be found to work equally well.

^{*} Mr. L. Gräff, "Installation of an Underground Ventilator at the Shamrock Pit, near Herne, Westphalia," *ibid.*, vol. xxxiv., B. page 234, *et seq.*

† Mr. Althaus "Application of the Known Laws of Air-motion to Researches on Ventilators, in particular the earlier Researches carried out on behalf of the Prussian Fire damp Commission in conjunction with Mr. Daniel Murgue," *Zeitschr. f. d. Berg-, Hütten-u. Salinen-Wesen im Preuss. Staate*, vol. xxxii., B., pages 174-236; *ibid.*, "Statistics of Ventilation Appliances in the Mines of the Kingdom of Prussia (April, 1883)," *Appendices*, vol. v., pages 1-77; "Final Report of the Sub-Committee on Ventilators," *ibid.*, pages 78-106.

‡ In the sense of Mr. Daniel Murgue's equivalent orifice of the mine, corresponding to the total frictional resistances of the pit (compare par. No. 120 of this Report).

On the whole, the slow-running big Guibal fans are suitable only for mines with large orifices, while the other smaller, quick-running ventilators are particularly suitable for mines with medium and small orifices.

For dealing with large masses of air from mines with large orifices instead of one big ventilator, two or more small ones, not connected with one another but sucking the air from one common airway, may be used with advantage.

119.—If artificial means of ventilation are to afford in any way the desirable degree of security, their performance must be continuously watched, and precautionary measures must be adopted for the event of any possible disturbances in working. As to the first condition, besides the application of the general rules for the supervision of ventilation which will be discussed subsequently, we should recommend the use of a self-registering check-apparatus (Art. 6 of the "Principles"). As to the second condition, it would seem advisable to hold substitutes in readiness, which in case of need could be immediately set at work either in the place of the ordinary apparatus or in support of it. In pits, where fans have been recently introduced such substitutes are mostly represented by the ventilation-furnaces, ventilation-stacks, etc., formerly used there and still kept in working order. For mechanical ventilators the presence of a second driving-engine, joined on to the fan by means of coupling, is in itself an invaluable adjunct.

The ventilation apparatus should only come to a standstill when there is complete cessation of work throughout the mine. If the apparatus stops working because of some accidental breakdown, every man in the pit should be brought to bank with the utmost practicable rapidity. This appears the more necessary, because repeated experiments conducted by the Sub-Committee on Ventilators* have unmistakably proved that (at any rate in the case of mechanical ventilators), contrary to the view held by many experts,† the persistence of movement of artificial air-currents in the pit is vanishingly small. The amount of depression caused by the ventilator always dropped with tremendous rapidity on the stoppage of the fan, and after a few minutes only the natural air-circulation of the mine (attended according to circumstances with a reversal of the air-current) was to be observed.

In order that an adequate air-supply may be assured, even in the event of such accidents as the influx of large quantities of fire-damp from the goaf or from freshly-hewn clefts or fissures, sudden outbursts of gas, fire-damp explosions, etc., there must be some means provided for increasing the volume of air to any extent that may be required. We should therefore recommend that in fiery mines the motors which are destined to produce the air-draught should be planned and maintained in such wise that the regulation minimum air-supply may at any moment be immediately increased by 25 per cent. (Art. 6 of the "Principles.")

Whether in any given case, this increase should be brought about merely by augmenting the velocity of the ventilator, or by harder stoking of the ventilating-furnace, or whether the installation of a second ventilator or a second furnace be necessary, depends entirely on the particular conditions of the mine.

Just as in putting down ventilation-furnaces the action of possible fire-damp explosions in the pit must be taken into account (compare par. No. 117 of this Report), so must mechanical ventilators be set up in such a manner as to suffer no

* *Appendices*, vol. v., page 85.

† Compare Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig., pages 99-100.

damage through an explosion. It is therefore advisable that the spot selected for the ventilator should be invariably some little distance sideways from the top of the upcast shaft, and that communication should be assured by means of an airway branching off from the shaft. Meanwhile the actual shaft-opening may be suitably closed only by a very light cover, and the main shock would strike straight through this in the event of an explosion. This is a precaution which should be the more heedfully observed that it is of enormous importance, immediately after an explosion, to be able to work the ventilator at its highest pressure for the purpose of restoring the momentarily disturbed circulation of air.

120.—*Airways and Air-velocity.**—The amount of air which is led through the pit is, on the one hand, in direct relation to the sectional area of the airways and the velocity of its passage through the mine, and on the other hand, it is in inverse relation to the frictional resistances of the pit. These latter are the greater according as the frictional-surfaces are greater, that is, according as the airways increase in perimeter and length, and that the air-velocity is greater; these frictional resistances also are the greater, the smaller the sectional area of the airways. Wherefore the shape of the sectional area, the character of the surfaces, the possible change in direction (twists and turns) of the levels or drifts, etc., are points which must be taken into account.†

In order to obtain a given air-supply with the smallest possible expenditure of power (or, what so far as its action is concerned is the same thing, with a given expenditure of power, to obtain the greatest possible air-supply) we see from what precedes that there are three principal means, viz., (1) great air-velocity; (2) short airways; (3) large sectional area and otherwise suitable disposition of the airways.

Apart from the fact that, concurrently with the increase of air-velocity, the frictional resistances are augmented proportionately to the square of that increase, and the expenditure of power proportionately to the cube, the practical limit to such heightened velocity is very soon reached. And this, not only because too rapid an air-draught is found injurious to the health of the workpeople in the mine, but more particularly because it introduces the risk of "blowing through" of the safety-lamp (compare par. No. 82 of this Report). Taking into account the ordinary conditions of Prussian coal-mining, the utmost possible air-velocity which the Commission regard as permissible is 240 metres (800 feet) per minute in the downcast, and 360 metres (1,200 feet) per minute in the upcast; as a general rule they consider it advisable to recommend very much lower velocities (see Art. 7 of the "Principles").

The length of airways is mainly influenced by the character or arrangement of

* Mr. Nonne, "Ventilation in Westphalian Collieries," etc., *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxi., B., pages 74-77; Mr. Hoerneck, "On Precautionary Measures against Fire-damp," etc., *ibid.*, vol. xxxi., B., pages 302, 319-320, 322-323, 325-327; Mr. Gurk, "On Ventilation," *Zeitschr. des Vereins Deutsch. Ing.* 1894, No. 43; Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig., pages 76-85; *Appendices*, vol. i., pages 162, 163, and 182; vol. ii., pages 133-138, 146-164; vol. v., pages 13-18, 36-39, 147-155.

† With regard to the total frictional resistances which certain particular mines oppose to the free passage of air, Mr. Daniel Murgue has introduced as standard of measurement the equivalent orifice of the mine (*orifice équivalent*); whereby, for the depression necessary to overcome such resistances, he calculates the sectional area of an opening in a thin plate sufficient at that depression to allow of the exit of the same volume of air. According as this aperture is very much more or very much less than 1 square metre (1976 square feet), according as it approaches or recedes from that figure, he classifies the mine as small, large, or medium. While practically all English collieries are very large, and all Belgian (nearly without an exception) are small, the equivalent orifice in those Prussian collieries which are provided with ventilators varies (according to the information obtained by the Sub-Committee) see *Appendices*, vol. v., pages 16-36, and plates i.-iii.) between 0.28 and 3.01 square metres (3.01 and 33.15 square feet), and therefore the Prussian collieries as a whole may be said to belong to the small and medium category.

the shaft (depending on whether there be one or two shafts, and on what is their situation and respective distance from one another), and largely also by the method of working the coal (compare para. Nos. 107 and 110 of this Report). But in any case the airways may be notably shortened by the provision of a suitable system of air-conduits, and most particularly by splitting the air-current. On the last named point we shall have something more to say in a subsequent paragraph.

The sectional area of the airways is a factor of very great importance in the provision of the requisite air-supply. Unfortunately, it so happens that until quite recently far too little attention was paid to this very point by those interested in Prussian coal-mining. In the course of their journeys of inspection, the Commission had the opportunity of ascertaining* that, while in nearly all collieries the sectional area available for the downcast current in shafts and main airways may be considered adequate for the purpose, the return airways as well as the upcast shaft or shaft-compartment leave much to be desired in this respect. Very often one finds in air-drifts and upcast shaft-compartments sectional areas which are hardly equivalent to the half of the sectional area in the main haulage-ways—and in almost all cases the first-named [sectional areas] are considerably smaller than the last-named. The consequence is that the requisite air-supply is secured only by means of such high velocities of air-draught as are not properly permissible, and there is a great waste of power in the working of the ventilators. The practically universal explanation of this unsatisfactory state of things lies in the fact that the present air-drifts are neither more nor less than old haulage-ways, and that at one time too little stress was laid on the value of wide sectional areas in the gateways [or galleries] (compare par. No. 109 of this Report). And then the original sectional area, such as it was, has been more or less narrowed down by such causes as pressure of the strata [roof], bulging of the floor or footwall, etc.

As a remedy for the future, the Commission consider it is of urgent necessity to rule that in the case of newly opened-up drifts and new shafts, the sectional area of main airways shall not average less than 3 square metres (32·29 square feet). (See Art. 7 of the "Principles.") For the purposes of this regulation, the following are to be reckoned as main airways (in addition to the upcast and downcast shafts or shaft-compartments):—The airways belonging to these shafts or compartments, all main cross-cruts and divisional cross-cruts, and all main level-drifts. As to the other deep level-drifts, midway level-drifts, air-drifts, and the longer air rise-drifts which are mostly traversed by split-currents, in certain seams a sectional area of 2 square metres (21·52 square feet) should be generally insisted on. Finally, for the ordinary holings betwixt every two galleries, for the galleries themselves, and for such airways as may be subsequently made in the stowing, a sectional area of 1 square metre (10·76 square feet) will probably be found sufficient, taking into consideration the multiplicity of air-splits which will by that time have been reached in the pit.

But admitting that the sectional areas above enumerated are really sufficient, they must be kept permanently free and open, a condition which needs more particularly to be observed in return air-drifts and upcast shafts. As to the return air-drifts, it should be a peremptory rule that for their protection sufficiently strong safety-pillars or barriers are left standing (or they should not be cut through seams that are being worked), that any breaking-in or narrowing which takes place should be set right as soon as possible, that tubs should not be parked in such drifts, that accumulations of waste-rock, timber, etc., be strictly avoided, that the tram-rails be always kept in a fit condition for traffic, and that the levels be more frequently

* *Appendices*, vol. I., pages 162-163, 182; vol. II., pages 134-138, 146-158, and 228-239.

examined to ascertain whether they are in the condition prescribed by the regulations. As far as possible, upcast shafts or shaft-compartments should be exclusively applied to purposes of ventilation; for other purposes, such as haulage of coal, or bringing of men to or from bank, they should only be used when their sectional area is very ample and when appropriate air-doors are so placed that the regular exhaustion of the foul air from the mine is completely assured.*

Next to the amplitude of sectional area, its shape and the general features [or disposition] of the airways, are points the importance of which can hardly be over-estimated. In theory and in practice the most suitable shape of sectional area appears to be the circle, for not only does it offer the smallest possible frictional surface, but is in every part used by the air-current with the greatest evenness and efficiency. It follows that where shafts are being newly put down, shafts which are intended to serve either for the admission or for the exhaustion of air, the circular section should be chosen in preference to all others: it has besides very great advantages in sinking and tubbing operations. Moreover, it would be in most cases preferable to allow an upcast shaft (even when this has to be used concurrently for haulage of coal or conveyance of men, see above) to act as an upcast throughout its whole sectional area, rather than to divide off from it (for ventilation purposes) a compartment of unsuitable sectional area, such as a segment of a circle with acute angles. In air-drifts it is advisable to avoid, so far as may be, any useless angles in sectional area; thus the roof, and the upper portion of the wall-face should be, to a certain extent, rounded off.

With regard to the other features of the airways, we may particularly call attention, firstly, to the advisability of smoothing carefully the rock-face [or wall], and this is best accomplished in conjunction with iron lining or masonry work; further, to the necessity of avoiding frequent and abrupt changes in the direction of the drifts.

How considerable a factor are the airways in the sum of practical progress towards a perfected ventilation of fiery mines, is strikingly set forth (by the Sub-Committee on Ventilators at the conclusion of the statistics of ventilation systems compiled by them) in the following words†:—

“Admitting that the ventilation of our mines, viewed by the light of statistics, forms on the whole an unsatisfactory picture, we must remember that the hope of future improvement lies less in the engineer, less in the perfection of machinery, than in the awakening of the colliery manager to the fact that here is one of his most important duties. His task it is to enlarge and to round-off, to ease by splitting or to shorten airways which are too narrow and too sharply bent. Only through spacious workings can large masses of air be drawn with economic advantage.”

“The ordinary security of working conditions, nay, the very life of the workmen, make an abundant provision of air at a moderate current-velocity a matter of prime necessity. If the colliery manager will simply look to this, that wherever the under-manager (having consulted his anemometer) reports an air-velocity of rather more than 200 metres (650 feet) per minute, the velocity of the air-current shall be, as far as possible, lessened by a corresponding widening of the airways; and if he will take care to diminish the friction in air-drifts by having them made with smooth walls, then the ventilating apparatus will (with rare exceptions) amply respond to the duty cast upon it of providing an adequate air-supply, and it will do so at a proportionately smaller expenditure of fuel.”

121.—*General Considerations on the Transmission of the Air-current and*

* Compare *Appendices*, vol. i., pages 178-179.

† *Appendices*, vol. v., page 39.

*Splitting of the same.**—In order to fulfil its aim with as near an approach to perfection as possible, the air-current should be led through the workings in such wise, that not only do all portions of these continuously receive the needful volume of fresh air, but the gases and foul air taken up by the current are removed out of harm's way. Whence we proceed to enunciate the following two fundamental principles:—(1) The air is to be led only in an ascending direction, and (2) the air-current must be split, more or less, according to circumstances.

The necessity of leading the air in an ascending direction arises partly from the progressive increase of temperature which the air-current undergoes on its passage through the pit-workings, partly from the low specific gravity of the deleterious gases which have to be taken up. Both these circumstances, in themselves, occasion a certain upward push of the air—a tendency which may be taken advantage of all to the profit of the ventilation. If this tendency be treated as a matter of no moment, it becomes one of the sum of resistances which have to be dealt with in the pit, and at certain points it may on slight provocation give rise to (dangerous) accumulations of gas. And it is, to say the very least, a risky mode of proceeding to allow the air-current to pursue a downward course after it has passed over a spot where fire-damp is known to occur. The Commission would therefore lay down the following regulation (Art. 8 of their "Principles") :—

"The ventilation must be so arranged, both as a whole and in detail, that the fresh air is led from the surface by the shortest possible route downward to the working-levels; but that thereafter the separate air-currents in the various working-districts shall follow an invariably ascending course."

As a matter of fact, in the course of their journeys of investigation, the Commission met with numerous cases wherein this rule (for very different reasons in each case) had been more or less widely departed from,† and yet in by far the greater number of these cases it was impossible to assert that any evil whatsoever had resulted from such departure. In several of them, indeed, one was compelled to admit that the downward ventilation method was the only adequate, the only practicable method. But this system (unless we have simply to deal with the leading off of a current which will not again be used) undoubtedly demands the greatest caution, and its application is therefore, in the opinion of the Commission, in at any rate the larger collieries, only exceptionally permissible, and then under special conditions (Art. 8 of the "Principles") :—

"Downward ventilation of workings in active use—with the exception of headings driven to the rise, where such ventilation cannot, of course, be dispensed with—is only allowable as an exception in consideration of the circumstances of the particular case, and subject to an abundant supply of fresh air and the provision of trustworthy bratticing."

"There appears to be no objection, on the score of danger, to leading downwards air-currents which are not intended to be made further use of."

Of equal importance, with the upward conduction of the air, is a suitable system of splitting the air-current. In pit-workings of any considerable extent, it is not only in view of shortening the airways and lessening the velocity, but in view of maintaining a good condition of the air, that there appears to be considerable

* Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig., pages 78-81; Dr. Kreisler, "Preliminary Report of the British Royal Commission on Accidents in Mines," *op. cit.*, page 11; Mr. Hoernecke, "On Precautionary Measures against Fire-damp," etc., *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxi., B., pages 307, 310-311; Mr. Gurli, "On Ventilation," *Zeitschr. des Vereins deutsch. Ing.*, 1884, No. 42; *Appendices*, vol. I., pages 16-17, 158-166; vol. II., pages 138-146, 165-201; *Final Report of the British Royal Commission on Accidents in Mines*, pages 10-13.

† *Appendices*, vol. I., pages 164-166; vol. II., pages 138-146.

advantage in splitting the air-current into a number of smaller currents, instead of leading it in one compact mass past all the working-places. Each of the split-currents provides a given district with fresh air, and then either re-combines with the other currents to form one main return current, or goes to day of itself. Where several levels are being worked at one and the same time, the splitting is best begun from the downcast shaft in such a way that each level receives the requisite supply of fresh air direct from the shaft, and therefore is not dependent for its air-supply on air which has already been used at a lower level. This method is attended with the additional advantage that the effects of a possible explosion will be, as a rule, restricted to one level only.

At each working-level, the split-currents for the respective districts generally branch off from the main crosscut, and in each district the air-currents for the various engine-planes or self-acting planes again branch off from the corresponding main gangway. To what extent the splitting is to be carried in each particular case depends on the method and conditions of working the mine and on the amount of fire-damp known to be commonly present. At all events the number of working-places to be supplied with air from one and the same current must be strictly limited, so that the air at the last of the points so supplied shall still possess the necessary freshness and purity. An air-current that is much fouled must be taken by the shortest way to the upcast, without being allowed to pass through any workings in active use (see Art. 9 of the "Principles").

As a matter of course, the general rule that the air is to be drawn [through the pit] only in an ascending direction must be implicitly observed in the case of split-currents [as well as in that of a single current]. Moreover, the various currents must be strictly separated [or partitioned off] from one another, and they should not be allowed to coalesce or pass through each other. The splitting-off of a current, and, as the case may be, its re-union with the main current or with the other split-currents should be so managed that sharp bends are as far as possible avoided, and that the cross-section [of the airway] is of amply sufficient area. Finally, it appears to us advisable that arrangements should be made enabling one at pleasure to temporarily reinforce and then weaken again any given split-current.

Among the principal auxiliary means which help one to arrange the transmission and splitting of the air should be mentioned air-doors [or airgates], airtight stoppings, air-crossings, and movable sliding-doors or regulators in the two first-named.

The air-doors should wholly or partially interrupt the air-current, that is, divert it in another direction or merely split it as the case may require, without at the same time interrupting the passage of men or the haulage of coal. They should close automatically, and at those points where an airtight partition is needful or where (in consequence of mining operations) there is a considerable amount of traffic going through, such doors should be at least double and placed at such a distance apart that one of the two doors will always remain closed. Air-doors which have become superfluous should be removed from their hinges. (See Art. 11 of the "Principles.")

Permanent stoppings of masonry appear to be suitable wherever the levels or other spaces so dammed off are no further needed for ventilation purposes or for other operations connected with mining. Among such places are the entrances to worked-out portions of the pit, and the lower openings of rise-drifts, holings, air-drifts, etc., which have ceased to be of any use. With such stoppings, just as with the air-doors, every care must be taken to see that they are in a continuously airtight condition. Where the stoppings are merely intended, by narrowing the sectional area of the airway, to split the air-current, they may be made of wooden planks with a suitable opening fitted with sliding regulator.

Air-crossings are intended to keep strictly apart from one another, two air-currents different in direction which happen to meet. This aim is best accomplished by leading one of the currents off in an airtight channel on the top (or the roof as it were) of the other.

In many cases no special distributing arrangements are necessary for splitting off a current from the main air-current or for further subdividing a split-current, provided the frictional resistances do not differ much in either direction and that the masses of air so split can be made approximately equal. It is, however, safer to provide an air-door, or, according to circumstances, a timber stopping, in which there is an opening with a sliding-regulator. In order to avoid undue pressure [from the pent-up air] it is advisable to make these openings so far as possible in the upper portion of the door or timber stopping, and of the greatest possible width, (that is to say they should be made in the form of an oblong slit rather than of a squarish aperture), or they should be arranged as "air-trapdoors."

The great stress which must necessarily be laid on the importance, wherever fire-damp is present, of a ventilation system consistently carried out on approved principles, leads one to this further conclusion, that for all fiery mines an accurate plan of air-distribution should be plotted out. In addition to the general plan, there should be separate tracings showing the course of the air [in each particular section of the workings] so that all the mining officials, besides possessing a complete *aperçu* of the general conditions of ventilation in the pit, may have at hand such local information as will enable them to take action at any particular spot where necessary. It may indeed be true that, with the rapid progress of the workings, such plans or tracings will need much alteration and addition; but they will greatly help all those concerned to understand what they are about, and it may happen that the pit will be thereby preserved (in certain cases) from the disastrous consequences of errors of omission or commission.

122.—*Conduction of the Air to the Working-face.**—If the ventilation of the mine is to be a practical success, it is not sufficient merely to provide that the fresh air shall be led through in abundant quantity—the important point is that the air should reach in the most direct way possible the working-face where it is required. The difficulties of this task are much enhanced by the fact that according to the conditions of each particular mine, it needs different means to overcome them; and still further by its dependence, for its successful accomplishment, on the attention, the goodwill, and the insight of the ordinary workman, quite as much as on the display of the same qualities in the officials. And thus it becomes easy to understand how it is, that precisely those comparatively short divergences from the direct, straight course of the air up to the working-face, are according to all experience so pregnant a factor in the genesis of fire-damp explosions.

Fresh air can only be led up to the working-face without further trouble where the method is longwall or overhand stoping, provided strict care be taken to make the [process of] stowing follow straight on the continual [inward] advance of the working. In pillar-and-stall work, on the other hand, and in all operations of opening and fore-winning this aim is attained by means of special arrangements the result of which is to rigidly demarcate the course that shall be followed by the air-current. These arrangements include, besides the air-doors and distributive sliding-regulators which have already been discussed (compare par. No. 121 of this

* Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig., pages 123-135; Mr. Hoernecke, "On Precautionary Measures against Fire-damp," etc., *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxi. B., pages 310-315, 325-331; *Appendices*, vol. I., pages 163-164, 183; vol. II., pages 152-154, 195-200.

Report) air-pipes or conduits, air-brattices, air drift-levels, air-headings, air-stentings, and air-boreholes.

The preliminary condition of the use of air-pipes (of wood, zinc-plate or sheet-iron) is an air-door wherein debouch the conduits which lead up to the working-face, and this door is either so placed as to be in the drift by which the air enters the mine (intake air-pipes), or so placed as to draw off the return air (suction or exhaust air-pipes). On account, however, of the considerable frictional resistance to which they give rise, such air-pipes—except in cases where they may be utilized in conjunction with hand ventilators (a point which remains to be discussed under the heading of “separate [or divisional] ventilation”)—are really efficient only with large cross-sections and short lengths [of airway]. Therefore, as a general rule, we are not inclined to advise their use.

Incomparably greater is the security afforded by air-brattices, as, thanks to them, one obtains two completely independent air-channels of approximately equal cross-section going right up to the working-face. They are built of brickwork, of airtight timbering, of canvas (sailcloth) stretched on a frame or hanging freely (air-curtains). The brickwork partitions are especially suitable for long cross-cruts, upbrows, self-acting inclined planes, etc., while the simple air-curtains are more suitable for the ordinary working places. It is of course unnecessary to add that the brattice must always be kept airtight, and continued as near as possible to the working-face.

In bottom and winning-levels of great width with extensive stowing, the stowing itself may with advantage serve as an air-brattice, an air-channel (for the fresh air which is to be led into the mine), being kept open in the stowing in the lower wall of the drift, while the actual headway is closed off by an air-door, and in its upper portion leads away the foul air returning from the working-face to the nearest rise-drift. An indispensable proviso in this arrangement is that the stowing should be very carefully built, and particularly that a rock wall as smooth and as airtight as may be should form the lining of the air-channel and of the gallery. We must admit, however, that this arrangement (just as much as the air-brattice method) has the great disadvantage in the case of a fairly widespread explosion of being easily destroyed, and thus, under given circumstances, the whole system of ventilation in an extensive area of workings may be brought completely to a standstill.

In opening out fiery coal-seams, it is preferable to push forward the deep levels, self-acting planes and other main galleries, simultaneously with a parallel air-road driven in the seam or the country rock: this air-road communicates at certain intervals (not too frequent) with the main gallery by means of holings. As a matter of fact, in this method of working the upper parallel gallery is driven somewhat in advance of the lower or main gallery, but then it should be the last to be traversed by the air-current, so that the gases which are here most abundantly evolved may be led off as directly as possible. In some cases it would even appear advisable not to drive both headings simultaneously, but in sections and alternately one after the other. Moreover, where there is much gas evolved it would appear absolutely necessary to lead an air-brattice over the distance (be it small or great), which intervenes between the last holing and the working-face in both drifts.*

Just as the parallel gallery system is applied in opening and fore-winning, so in pillar-and-stall work is the air communication betwixt the separate working-faces assured by means of air-holings (rise-drifts in longitudinal pillar work). To

* For such preliminary headings in fiery seams, we should recommend in preference to others, the Hilt suction-process (compare par. No. 103 of this Report).

allow of the fresh air coming up as near as possible to the working-face, the individual holings should not follow each other at too great distances. The Commission hold the view that in no case should the face where the coal is being worked be more than 20 metres (65 feet) distant from the direct air-current, that is from the nearest holing, and therefore the interval between each of these holings should never exceed 20 metres (65 feet). And even with so small an interval as that, it will be as a rule advisable (in order to avoid accumulations of gas at the working-face) to place from the last holing to the face a movable air-brattice (sail-cloth) for the fresh air.

Of late years, particularly in Westphalian collieries, holings have been largely discarded in favour of air-boreholes.* From the point of view of safety the latter have over the first-named this considerable advantage that they entirely do away with the always risky process of driving an upbrow to the rise. It is true, however, that on account of their generally small cross-section these boreholes do not allow of a man making his way through them: given certain circumstances—say, the necessity for instant flight in the case of an explosion—the defect may prove very serious indeed. Assuming that such objections are met by making the diameter of the boreholes larger or by partly widening the borehole (after holing), then air-boreholes will be found adequate to all the expectations that can be formed of them.

As far as the convenient utilization of the various means of air-conduction at different points of the workings is concerned, preference should be given in shafts, cross-cruts, and other galleries to the parallel air-way system of driving. But even for these, air-brattices, air-pipes, or conduits will be found sufficient if they have a large enough cross-section. One or other of such means is an indispensable accompaniment to any operations of that kind in a fiery mine. In all upbrows driven to the rise, special ventilation is requisite, but this need only be done in galleries driven to the dip when these are longer than 15 metres (49·3 feet).

The air-stentings or air-boreholes which have to be arranged in parallel gallery working and in pillar-and-stall work should follow one another at intervals of at most 20 metres (65 feet). The corresponding drift must not be lengthened beyond that distance before the new holing has come to the junction. Simultaneously with these operations all air-drifts and holings which have become needless for ventilation purposes should be hermetically and permanently sealed up (see Art. 10 of the "Principles")

123.—Separate Ventilation.†—Even with the most carefully managed conduction of the air, it is not always found practicable to have every working-place

* *Appendices*, vol. ii., page 154.

† Messrs. B. R. Foerster and R. Hausse, "Observations on the Character and Motion of the Pit-air in the Royal Collieries in the Plauen'scher Grund, together with General Remarks on Pit Ventilation," *Jahrb. f. d. Berg-u. Hüttenwesen im Königr. Sachsen*, 1879, page 1, et seq.; Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig., pages 105-116; Mr. Gurit, *The Prevention of Fire-damp Explosions in Collieries*, Bonn, 1880, pages 21-22; Mr. Pelzer, "Ventilation of Mines," *Glückauf*, 1882, No. 49; Mr. Schroeder, "Separate Ventilation of Pit-workings by means of Compressed Air," *ibid.*, 1884, No. 25; Mr. B. R. Foerster, "On Separate Ventilation and its Cost," *Jahrb. f. d. Berg-u. Hüttenwesen im Königr. Sachsen*, 1882, page 4, et seq.; Mr. von Steindell, "On Separate Ventilation in the Pit-workings of the Zwickau-Oberhohndorf Colliery Association," *ibid.*, 1884, pages 79-91; Mr. Menzel, "Review of the Labours of the Saxon Commission," *ibid.*, 1886, page 11; Mr. Simmerbach, "On Ventilation in Fiery Mines," *Berg-u. Hütten-Zeitung*, 1885, No. 20; Mr. C. Th. Meyer, "Theory of the Effect of Suction-pipes utilized in separate Ventilation," *ibid.*, 1887, Nos. 9-14; Mr. Hoernecke, "On Precautionary Measures against Fire-damp," etc., *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxi. B., pages 315-316, 330-331; Mr. von Steindell, "On the Ventilation of Fiery Mines," *Zeitschr. des Vereins deutsch. Ing.*, 1884, No. 3; Mr. Gurit, "On Ventilation," *ibid.*, 1884, No. 42; Mr. B. Otto, *Fire-damp and no Aim of Providence*, Berlin, 1886, pages 47-62; *Appendices*, vol. i., pages 183-186; vol. ii., pages 202-208.

efficiently traversed by the main air-current or by a split-current, without the air being seriously weakened or being repeatedly led downward. It is therefore advisable, above all in mines with small orifices, to provide with air, by means of separate ventilation, such portions of the workings as are particularly remote or specially in need of air, independently of the traversing air-current. The simplest ventilation system of this kind is that of hand-ventilators (or air-mills) in conjunction with air-pipes, such as have been in use for a great many years in all coal-mining districts of the kingdom of Prussia (in connexion with the working of rise-drifts known to contain fire-damp). The Rittinger or Schiele centrifugal ventilators are mostly used for this purpose, but of late years the much more efficient Pelzer spiral ventilators have begun to supersede them, and in some few districts Roots blowers have come into use.

Whether the hand-ventilators will best fulfil their purpose by exhaustion or by compression is a matter which should be decided according to the circumstances of each particular case. On the whole, the compression method will no doubt be found preferable; for it is evident that the powerful mechanical action of the compressed air-current will largely help to keep the actual working-place free from the invasion of fire-damp, and the air will be constantly reaching the hewer at the working-face in the freshest possible condition. By the exhaustion method, on the other hand, the air, before it comes to the working-place, will have taken up the gases evolved in the lower portion of the drift. It is true, however, that the drift itself is supplied with better air by the exhaustion process. In every case the rule must be strictly adhered to of setting up hand-ventilators only in the fresh air-current (Art. 10 of the "Principles"). If they work by exhaustion, there must besides be a return air-pipe available, by means of which the foul air is led away directly into the return air-current, that is, into the nearest return air-way, and thence onwards to the upcast.

Where such a ventilator has to be worked continuously for a long stretch of time, or where it has to provide several points simultaneously with fresh air, it will be best to substitute machine for hand power. Supposing steam is not locally available, one may select some such appliance as a small water-turbine, or engines driven by compressed air, or transmitted electric power.

The many dangers which may arise as a consequence of bad installation or negligent management of the hand-ventilators, as well as the inadequate efficiency of the latter over great lengths [of workings] led to the following arrangement being adopted in many fiery mines somewhere about the middle of the 'seventies. In opening and fore-winning operations, and particularly in driving to the rise self-acting inclined planes and other fairly long upbrows, apart from the main air-current, compressed air is used for the local ventilation. This method possesses the, by no means despicable, advantage of leading up to the respective working-places, quite independently of the actual air-supply [of the mine], fresh air direct from day: and at the same time the compressed air on its return journey at ordinary density produces cold, and so has a cooling effect on the pit air. One thing which militates against a more extended use of compressed air is its very high cost of production.

The method, at one time exclusively in use, of simply allowing the compressed air (brought up to the working-face in pipes) to stream out in front of the working-face may certainly have the effect of dispersing the deleterious gases which are evolved there, but from the economic point of view it involves evidently a great waste of power. It should therefore be restricted to such localities as need comparatively little air, with considerable length of drifts or high rock-pressure (pressure of the strata.)

A much improved method of utilizing compressed air is to let it stream out after the fashion of the Giffard injector, from a narrow aperture into an open pipe. Then, thanks to the dynamic power of the compressed air, a not inconsiderable volume (12 times its own and more) of free air is swept along with it into the air-pipe. Peculiarly suitable for this purpose is the Körting jet apparatus, whereby the air streams into the channel through a number of concentric nozzles. Meanwhile the usual simple exhaust aperture is sufficient [for ordinary purposes.]

Such apparatuses may be applied either on the compression or on the exhaustion system. In the first case the pipe must of course start with its orifice somewhere within the area traversed by the fresh air-current. Their permanent use, particularly in haulage roads, has been of late years much extended, as, for instance, in the Maria pit at Höngen, near Aix-la-Chapelle, in several pits of the Lower Rhenish-Westphalian coal-basin, and in the collieries of the kingdom of Saxony. The very convenient arrangement has been adopted of making the exhaust aperture of the compressed air variable (differential blower), so that the ventilation (air-supply) of each working-place can be increased at any time as may be required.

The Commission believed it was their duty to recommend warmly separate ventilation by compressed air and pipe-jets, and also by means of the Körting and other appliances which appear suitable for the air-supply of localities that particularly need air. (See Art. 10 of the "Principles.")

In the same manner as compressed air, water-pressure, in combination with the Körting spray injectors, may be used with advantage for local ventilation of the more remote working-places.

In the Friedenshoffnung and Karl Georg Victor pits near Waldenburg (Lower Silesia), where the seams contain much gas, a system of separate ventilation of the fore-winning headings and even of the galleries in the respective self-acting plane districts has been carried out by means of large compression pipes, coupled with artificial damming back of the fresh air-current and considerable depression of the return air-current.* The fresh air dammed back by the air-doors is led up to each particular working-face through lengths of large wooden boxes (air-headings, deep levels) or through ordinary zinc-plate pipes (haulage-roads). Thence, laden with the gases taken up at the working-face, the air escapes freely (without coming into contact with any other working-place) through the successively superposed air rise-drifts into the uppermost airway. The air-doors are situated immediately in front of the last driven upbrows of the respective levels, and thus the conduits which go from them are always short. On the other hand, the upbrows which lie farther behind and the self-acting inclined plane are carefully shut off from the air-drift in order to obviate waste of air. The excess depression needful for damming back the air in the self-acting inclined planes, which has to be attained by the ventilator, amounts in the Friedenshoffnung pit to about $\frac{1}{2}$ inch (about 12 millimetres) of water-gauge, or $1\frac{1}{4}$ inches against 1 inch (37 millimetres against 25 millimetres.)

Although this method of separate ventilation, when compared with the more usual systems, unquestionably necessitates a greater expenditure of motive power, its very high efficiency impels the Commission to declare the use of the method extremely suitable in those cases where—the special local conditions of the mine, offering great difficulties—an adequate supply of fresh air is available with a sufficient depression.

124.—*Superintendence of the Ventilation.*—Even where the ventilation arrangements are of the most perfect description, absolute security against accumulations of

* *Appendices*, vol. I., pages 183-186.

fire-damp can only be assured by the most rigid adherence to regulations. In the first place, care must be taken in every fiery mine that there is a continuous and reliable surveillance of the system of air-conduction in its broad lines and in its details, this surveillance to be carried out (if need be) by officials employed for that purpose alone (see Art. 18 of the "Principles"). And yet hitherto this work has been mostly performed by the ordinary mining officials (viewer, underviewer, overman) in the course of their regular tour of inspection through the pit. But this divided attention, this piecemeal supervision has now become entirely inadequate in the larger pits in view of the increasing importance and difficulty of ventilation. And thus of late the very proper course has been largely adopted of appointing for the special purpose "air-overmen," assistants to the overmen, who either take over the entire supervision of all matters in the pit which appertain to the conduction of the air, or at the very least that of the main air-currents; in the latter case, the district overmen are responsible for the condition and distribution of the air in their respective districts.

What above all things constitutes an essential aid to a proper supervision of the ventilation is, in addition to daily sampling of the air of the pit-workings and occasional chemical analyses of the return air-currents (compare pars. Nos. 100 and 101 of this Report), regular measurements of the air.* As a result of the journeys of inspection of this Commission there has come more and more into use the highly appropriate arrangement of permanent measuring-stations (with an exactly determinable cross-section lined with planking). The measurements taken at the most important points by the air-overman, once a week or oftener, are found (in conjunction with the already discussed check-apparatus at the ventilators, etc., see par. 119 of this Report) not only to allow of the efficiency of the ventilation arrangements in all their details being accurately gauged, but to furnish the data for such improvements in the system of air-conduction as may be necessary. The results of these measurements and of the air supervision as a whole are registered in the "Ventilation Journal," together with the daily barometer, thermometer, and weather records. Those mining officials whom it may concern and the manager of the mine make themselves, of course, acquainted with the contents of this journal. Such a mode of procedure is undoubtedly of the very greatest value in matters of ventilation, and its universal application in all fiery mines is highly desirable.

In addition to exercising proper supervision over the ventilation, the rule must be strictly observed of allowing no alterations in the arrangements for regulating the air-currents to be undertaken without the special authorization of the supervising official [whom it may concern]. Further, all the men at work in the mine are in duty bound to report at once to that official any cases of damage to the air-brattices, air-doors, air-pipes, and in short every irregularity in the ventilation (see Art. 12 of the "Principles").

125.—Measuring and Check Apparatus.†—As a means for measuring air-velocities and air-volumes, the Casella fan anemometer with aluminium blades is practically the only instrument adopted in Prussian coal-mines. The Commission in the course of their investigations also made use of such an anemometer, supplied

* Compare *Appendices*, vol. i., pages 172, 182, and 190; vol. ii., pages 215 and 217; vol. v., pages 11-13.

† Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig., pages 85-90; Mr. Agullon, "Mechanical Control and Inspection of Mine Ventilation," *Annales des Mines*, series 7, vol. xx. (1881), page 248, et seq.; *Final Report of the French Fire-damp Commission* (German translation), op. jam cit., pages 293-294; Mr. Hoernecke, "On Precautionary Measures against Fire-damp," etc., *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxi. B., page 306; Mr. Althaus, "Application of the Known Laws of Air-motion," etc., *ibid.*, vol. xxxii. B., pages 178-180, 183-186, 209-215; Dr. Serlo, *Treatise on Mining*, 4th ed. (1884), vol. ii., pages 338-346, 395-396; *Appendices*, vol. v., pages 11-13, 83-85, 107, et seq.

by Mr. R. Fuess of Berlin. Although in some few cases its rather high velocity-constants ($32\frac{1}{2}$ feet and more per minute) gave rise to some little difficulty, inasmuch as they did not allow of the measurement of slowly moving split-currents, yet, on the whole, this instrument has been found extremely handy, convenient, and quite sufficiently durable for purposes of air-measurement. For measuring feeble air-currents the larger anemometer with mica blades (velocity-constant $9\frac{1}{4}$ feet) recently brought out by Mr. Fuess appear more suitable. It is, however, to be observed that with high air-velocities there is a risk of some of these fragile blades being broken, and the instruments show now and then divergences from the constant formula. The larger anemometers with mica blades constructed by Mr. G. Rosenmüller, of Dresden, are also said to be very sensitive and to give trustworthy indications with velocities as low as 7 metres (23 feet) per minute.

In order to shorten, as far as possible, the time devoted to a single measurement, the Sub-Committee on ventilators, instead of allowing the anemometer to register during three to five minutes and sliding it in and out of gear by hand, made use tentatively of a Casella anemometer which was automatically released by clockwork after registering for one minute. But this was found to give rise to considerable inaccuracies. The use even of electric appliances was attended with many difficulties, and, on account of the elaborate preparations necessary and the numerous derangements of all kinds which so often took place, offered no advantages so far as gaining time was concerned. We must, therefore, conclude that for air-measurements made in the ordinary course of mining operations, the old method of sliding in and out of gear by hand will have still to be adhered to.

The observation already recorded by the Committee on Ventilators of the Gard coal-field, that all anemometers whose formula is calculated by testing in still air with the rotating wand machine (anemometer in motion), register far too high values in the actual air-current (anemometer at rest)*—has been proved strikingly correct, after careful comparison of several anemometers in an air-current of accurately known velocity. It has further been shown by the detailed researches of a member of this Commission, Mr. Althaus,† conducted with a large gasometer filled with air, that the exaggeration of values increases directly as the air-velocity. Thus, according to these investigations, the plus-value registered by the Casella anemometer at velocities of 50, 250, and 500 metres (164, 820, and 1,640 feet) amounted to 3·72, 7·35, and 11·90 per cent. (respectively) of the actual current-velocity, and the Robinson anemometer showed far greater exaggerations. It will be therefore indispensable in future to subject the anemometers to a more careful testing, and to repeat the tests more often.

In addition to the Casella anemometer, the Sub-Committee on ventilators made an extensive use (with very favourable results) for the measurement of air-velocities of the Pitot tube or pipe, particularly in the air-drifts of the fan‡: this apparatus is usually applied to the measurement of water-currents. In conjunction with it, they at first used as a manometer, single-limbed, inclined glass tubes connected on to a water-recipient, with a twenty or thirtyfold enlargement of the liquid column. Subsequently they made use of handier two-limbed tubes, both limbs of which could be set in an inclined plane at any angle of inclination that might be selected; and, in order to obviate the drawback of adhesion to the sides of the tube, the water-filling was replaced by an aqueous solution of alcohol (67 vols. per cent. alcohol, sp. gr. 0·9).

* Compare Mr. Althaus, "Application of the Known Laws of Air-motion," etc., *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxii. B., pages 182-186.

† "Physical Researches with a Gasometer of the Municipal Gasworks at Breslau," *Appendices* (to this Report), vol. v., pages 107-167, and published separately, Berlin, 1887.

‡ *Appendices* (to this Report), vol. v., pages 83-84.

Measurements with the Pitot tube, compared with those recorded by ordinary anemometers in currents of considerable velocity (more than 9½ feet per second) show far greater accuracy, and should on that account alone—quite apart from the fact that they are also very much more conveniently obtained—be preferred in many cases to the unreliable anemometer measurements. Our colleague, Mr. Alfons, in the course of the above-mentioned gasometer experiments, determined accurately the formula [for the Pitot tube].*

In the course of these experiments also it was found possible to test exhaustively the system introduced by Mr. Dan. Murgue, which consists in a purely mathematical measurement, that is, in measuring air-velocity by the outflow through apertures in a thin plate; and Murgue's formula was, on the whole, confirmed.† This system appears peculiarly adapted to the determination of the air-volumes of very feeble split-currents, which, on account of their low velocity, cannot be measured by means of the anemometer.

Very considerable difficulty is met with in all air-measurements in determining in the drift cross-section, the point where the measuring instrument ought to be set up, so as to register as nearly as may be the average (mean velocity) of the air-current. Numerous experiments have demonstrated that in regular straight drifts the velocity attains its maximum somewhere about the middle of the cross-section, and diminishes thence evenly towards the sides. But this rule is subject to so many exceptions, conditioned by local circumstances, that it appears impossible to fix on a particular point of the cross-section as being universally that where the velocity attains its mean value.

As a means of overcoming this difficulty to some extent Dr. Schondorff has sought, by exhaustive experiments‡ to obtain certain coefficients of approximation corresponding to the relation between the actual air-volume in the whole cross-section, and that inferred from the measurements made in the middle of the cross-section. The coefficients calculated by him are: for drifts with ordinary wooden timbering, 0.75; for unlined drifts in massive rock, 0.80; and for drifts with complete brick lining, 0.85. But, according to Mr. Murgue's§ experiments these coefficients do not seem to hold good universally, and there were, for example, in the relation between the true mean velocity and that found in the centre of the drift (cross-section) divergences, varying from 0.68 to 1.12.¶ It would therefore seem preferable to always undertake measurements at various points of the cross-section and strike the average of those.

In the course of the investigations carried on by the Commission, the air-volumes were partly determined according to the Schondorff system (district section of Bonn), and partly by measurements taken at two or three points of the drift cross-section (districts of Dortmund and Breslau). The Sub-Committee on ventilators always made observations at as many points as practicable, distributed evenly over the cross-section under measurement, and as many anemometers or Pitot tubes as there were measurement-points were used simultaneously.

For current measurements in the ordinary practical working of mines, at measuring-stations specially arranged for that purpose (compare par. No. 124 of this Report) there is this important simplification—that at each particular station, the

* *Appendices*, vol. I., pages 131-135, 139-140.

† *Ibid.*, pages 123-131.

‡ "Examination of the Return Air-currents of the Saar collieries," *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxiv. B., pages 79, 120-125.

§ Compare Mr. Aguilon, "Mechanical Control," etc., *op. jam cit.*

¶ Many recent observations in the collieries of the mining district of Aix-la-Chapelle have led to similar results, and especially did the air-volumes, reckoned by means of the Schondorff coefficients, almost invariably turn out to be too low.

relation of the air-velocity (at a particular selected point) to the true mean velocity may be accurately determined once for all, and then the process of measuring may be subsequently limited to that fixed point. The previously mentioned experiments of Mr. Murgue have, to all intents and purposes, demonstrated that in one and the same cross-section, the velocity at each single point varies in exactly the same proportion as the mean velocity.

For such air-measurements in the pit, we should moreover recommend the use of light portable stands, which the official whose duty it is to take the measurements would carry with him for setting up the anemometer. Or, if more convenient, some equivalent arrangement could be made at each measuring-station; in any case, the operation is likely to be better performed and the results to be more trustworthy, when the anemometer stands on a firm basis than when it is held in the hand by the person who is engaged in making the measurements.

As a check apparatus for ventilators in Prussian collieries, in addition to the ordinary water-gauges* (which show the depression in the air-drift to the fan), together with the stroke-counters at the engine itself, the only instrument in use is the Ochwaldt self-registering water-gauge.† This gives a faithful picture of the rise and fall from minute to minute of the readings of the water-gauge, varying according to the speed of the ventilator, according to the influence of changing resistances in the pit or of the wind at the surface. On the one hand it enables the engineman (before whose eyes the line is traced), to strictly regulate the speed of the ventilator according to the requirements of the mine, while, on the other hand, being secured by means of a lock from any possible tampering on the part of the engineman, it furnishes the managing officials with an all-embracing means of control. The Commission have therefore no alternative but that of warmly recommending the use of this apparatus.

IV.—PRECAUTIONARY MEASURES AGAINST EXPLOSIONS.

1.—General Observations.

126.—Regular Examination of the Workings.—Not even the very best system of ventilation affords an infallible protection against accumulations of fire-damp. So far from that being the case, one must always keep in view the possibility of such accumulations—whether as a consequence of accidental disturbances of the ventilation or of a sudden (or extraordinarily abundant) evolution of gas. In addition, therefore, to scrupulous care in the management of the ventilation, it would appear necessary to take such measures as may most effectually minimize the danger of explosion of the gases which may have accumulated.

In the forefront of such measures is the regular examination of the pit workings with a view of ascertaining the presence of fire-damp. This should extend to every working-place, and should be carried out before the workmen are allowed to enter it (Art. 15 of the "Principles"). Under ordinary circumstances, the examination should be carried out in two ways: once by special overseers (master wastemen) for the whole pit or ventilation-district, and then, quite independently, by the fireman or deputy overman for each single working-place (compare par. No. 100 of this Report). The utmost care is needed in conducting this examination, especially on the morrow of holidays or Sundays or after any cessation of active work, and the same caution is necessary when there are sudden changes in the weather or a sharp fall or rise of barometer.

* And also those with an inclined outer limb for enlargement of the scale.

† Mr. H. Ochwaldt. "On the Self-registering Water-gauge (German Imperial patent, 4510) and its Application in Prussian Collieries," *Berg-, u. Hüttenmännische Zeitung*, 1885, No. 21.

127.—Measures to be taken when Fire-damp is present.—If the examination reveals the presence of fire-damp at any point whatsoever, the passages leading to that spot should be at once fenced off, and the men should not be allowed to enter it until the superintending official (who will meanwhile have been informed of the state of affairs) has made the arrangements which the circumstances demand.

Supposing that dangerous accumulations of fire-damp are noticed in certain parts of the workings in the course of a shift, the workmen should quit those places, fence them off, inform such of their fellow workmen as are likely to incur any risk by approaching the dangerous localities, and report the circumstances to the first mining official whom they may reach (Art. 16 of the "Principles"). A similar procedure should be observed when in fore-winning, in the neighbourhood of old workings, etc., fire-damp is met with.

In all such cases of local accumulations of fire-damp, there is one point upon which it is advisable to insist, viz., that the removal of the obnoxious gas should only be attempted under the direction of the mining official whom it may concern, or of an overseer appointed by him; and that in no case should it be proceeded with even then, until there is absolute certainty that the foul air can be led off in such a way as to avoid endangering the security of other working-places or other workmen in the mine.

128.—Fencing-off (or other means of distinguishing) Dangerous Localities.—In just the same way as the working-places, where fire-damp accumulations are found to occur, are fenced off, so should portions of the pit which are not worked for the time being, be fenced and the men forbidden to go into them (Art. 13 of the "Principles"). Sufficient for such purposes are simple signs of warning, well understood by the pitmen. As, for instance, crosses chalked on the coal-face, boards hung up, or chains, or crossed poles, etc., or best of all a real timber fence. If a certain portion of the workings is to be abandoned temporarily or permanently, it will be best to completely stop that portion up with stone-packing.

In districts wherein the use of naked lights is generally considered permissible, the passages communicating with such localities as show the presence of fire-damp should be marked in a clear, unmistakable manner, and miners should be strictly forbidden to approach them with naked lights. Similarly, in all working-places that are examined for gas by the overman before the miners go down the pit, it will be the duty of that person to define exactly the stations where the men must remain for a time, until the atmosphere of the working-place is properly purified.

129.—Measures to be adopted in cases of Disturbed Ventilation.—If there be considerable disturbance of the ventilation, no time should be lost in removing the men from the now dangerous workings, and the workmen must not go back to those places until they have been declared perfectly safe, as a result of a properly conducted examination for gas (see Art. 16 of the "Principles"). It is particularly advisable in those pits which are artificially provided with air by means of a ventilator, that any chance stoppage of the ventilator (resulting from damage to the engine, etc.) should be as soon as possible made known to the underviewer and other mining officials. These responsible persons will thus be enabled without delay to make such arrangements as they may deem necessary. The announcement of the stoppage should, moreover, be immediately transmitted to those in charge of the winding-shaft.

If, for purposes of repair or other reasons, it is found needful to stop the ventilator for a time, the officials will do well to begin by assuring themselves that all the miners have been brought to bank. Before anyone is allowed to go down the pit again, the ventilator must have resumed regular working for a few hours at the very least.

With regard to increased activity of the ventilation necessitated in consequence of barometric changes, and the regular barometer, thermometer, and weather observations which are to be carried on for this purpose, we would refer the reader to other portions of this report (compare pars. Nos. 70 to 73).

130.—Other General [Precautionary] Measures.—The rule must be stringently observed that any ignition or explosion of fire-damp, even when no injury to persons arises therefrom, must be immediately reported to the manager. The latter will then conduct on the spot an enquiry into the details of the event, and will hear the evidence of those who were present when it occurred.

Even in pits or portions of workings where so far no fire-damp has been detected, it would appear necessary in opening up new drifts or new districts to make frequent examinations for any traces of gas; and for that purpose a certain number of safety-lamps should be kept in readiness. The inspectors of mines should be immediately informed of any occurrence of fire-damp.

It would further appear desirable to arrange matters so, that at every point of the workings where fire-damp is either known to occur or expected to occur, there should always be at least two men working together—and if this be impracticable (as in narrow places), one should see to it that other men are at work in the immediate vicinity.

Smoking, and the carrying about one's person of tobacco, pipes, and lighting materials (excepting steel, flint, and tinder) must of course be strictly forbidden in all fiery mines.

2.—*Lighting of the Pit.*

131.—Prohibition of Naked Lights.—On account of the generally feeble light emitted by safety-lamps, their exclusive use has hitherto only been insisted on (except of course for previous examination of the workings) in such portions of the pit as really betray the occurrence of fire-damp. Otherwise the use of naked lights has been freely allowed. But this mixed system gives rise to at least one very serious risk (quite apart from the possibility frequently demonstrated by experience, that workings at one time apparently free from gas may sooner or later be invaded by fire-damp), and that is, the impracticability, especially in very extensive workings, of dividing off the fiery districts from the non-fiery districts so exactly that there will be no likelihood of workmen passing carelessly with naked lights from one district to the other. As a matter of fact statistics are at hand to show that very many fire-damp explosions are really attributable to this mixed system.

The Commission are of opinion that a change can be wrought in this direction only by means of a general prohibition of naked lights throughout all fiery mines; and it is for that reason that in Art. 20 of the "Principles" the Commission have expressed themselves as follows:—

"In no fiery mine is the use of naked lights below ground permissible. Only safety-lamps and electric incandescent lamps may be used."

Exceptions to this rule are regarded by the Commission as allowable, only within the downcast fresh air-current in the [downcast] shafts and at the corresponding ingates, and in some very special instances in the upcast (return air) shafts.

As it has so far been found impossible to manufacture a sufficiently cheap and simple portable electric lamp for the miner (compare par. No. 87 of this Report), ordinary safety-lamps will, for the present at any rate, constitute the sole means of lighting fiery mines.

132.—Construction of the Safety-lamp.—The experience of all countries has shown us that no single one of the innumerable varieties of safety-lamps which have been invented gives absolute immunity from ignition of fire-damp. Indeed,

considering the nature of the safety-lamp and the uses to which it has to be applied, it seems hardly probable that any lamp offering the guarantee of absolute immunity will ever be invented. But it is none the less certain that the lamps hitherto in use are capable of much improvement, which should take the direction of making them as perfect a means of warning and of protection as is practicable in the hands of the miner. With reference to this point the Commission, taking advantage of the exhaustive researches of their Sub-Committee on lamps, have set forth a series of requirements and recommendations (compare par. No. 86 of this Report, and Arts. 21 and 22 of the "Principles") as to the construction of the safety-lamp, and if these be duly complied with, there is every reason to hope for a greatly increased measure of security [in the use of the lamp].

Although it must be fully understood that the Commission are by no means of opinion that any and every sort of safety-lamp is suitable for use in fiery mines, they hold that it is equally undesirable to prescribe for universal use a particular safety-lamp of unalterable type (as, for instance, is the case in Belgium with the Mueseler lamp)—because there is no room for doubt that a regulation of that kind constitutes a vexatious obstacle to further improvements.* Similarly the majority of the Commission declined to entertain the proposal that official testing-places should be set up for the investigation of all newly invented lamps, and that only the use should be allowed in mines of such lamps as have been found sufficiently safe by the testing officials. The Commission held that the necessary observations and watching of results would be best accomplished by the mining officials themselves.†

133.—*Supply and Maintenance of Safety-lamps.*‡—Considering the great importance which, in fiery mines, attaches to the keeping of safety-lamps in permanently good condition, it appears entirely out of the question to entrust the supply, repair, and cleaning of the lamps to the workmen. So far from that being permissible, it is the duty of the managing officials to get the necessary lamps, to supply them, and to keep them in proper order (Art. 23 of the "Principles").

In the course of their journeys of inspection, the Commission had the opportunity of observing that in Prussian mines the present state of matters as regards safety-lamps leaves very much to be desired, at least, from the point of view of safety. The first step towards thorough reform would be for mine managers to insist in future, when inviting tenders for lamps, not only on more stringent conditions as regards lamp construction, on good sound materials and unexceptionable workmanship, but on making arrangements to submit every lamp delivered to them, as a whole, and in each of its parts, to a most searching test. In this connexion it would be advisable to have in readiness apparatus by means of which the lamps are examined as to their airtight condition. An apparatus of this kind which has in several cases given satisfactory results is the Wolf tester; within its spiral tubes, the ignited lamp is surrounded on all sides by benzine gases.§

Similarly, more care in the future will be needful in keeping the lamps in a proper place and in good order. For this purpose lamp-rooms should be erected near the point where the miners enter the pit; and men (lamp-men or lamp-cleaners) should be specially employed, whose sole duty would consist in cleaning the lamps after use, in examining them carefully and making any needful repairs. They would also look after filling the lamps with fresh oil, etc., and would themselves light and

* The British Royal Commission on Accidents in Mines also express themselves in their *Final Report*, page 118, as opposed to the exclusive official prescription of any particular pattern of lamp.

† The British Royal Commission on Accidents in Mines, *Final Report*, page 118, consider it desirable that some control should be exercised over the use of lamps in mines, and that only such lamps should be allowed as meet with the approval of the Secretary of State.

‡ *Appendices*, vol. iii., pages 28-33, 187.

§ *Appendices*, vol. iii., pages 30-31.

lock the lamps when these are about to be used. Naturally, these men would require careful and constant supervision; and, among other precautionary measures, it would be necessary to have periodical and searching inspections of all the safety-lamps used in the mine.

The lamps should be dealt out by the lamp-man to each miner, lighted and locked, before he goes down the pit; and when his shift is over, the miner must return the lamp (still locked) to the lamp-room. The workmen should be strictly forbidden to take the lamps away with them to their dwellings. In cases where the miners themselves light and lock the lamps (a practice still followed in some localities), an inspector should be specially detailed to stand at the entrance of the pit and examine the lamp of each miner as he goes in, in order to assure himself that the lamp has been locked in compliance with the regulations. On the other hand, it will be the miner's duty to make sure, immediately the lamp is handed to him, that it is in perfect condition. For this purpose, arrangements should be made (similar to those already mentioned in connexion with the testing of newly-delivered lamps) for the trial of the burning lamp in an inflammable mixture of gas and air.*

For the better carrying out of the lamp supervision generally, it would be well to have all the lamps in use in any particular pit numbered consecutively, and to let the same man always have the same lamp (see Art. 23 of the "Principles"). There is an additional advantage attendant upon this arrangement (from the point of view of safety as a whole), namely, that at any moment persons stationed in the lamp-room can determine exactly how many men have gone down the pit and how many have come to bank again.

134.—Use of the Safety-lamp in the Mine.†—The moment the miner has got the lamp in his hands, he becomes responsible for it and answerable for the due observance of the rules which govern its use in the pit. Opening of the lamps must be severely prohibited in the case of all miners, and permitted even for inspectors and officials only in very special circumstances. Such lamps as may chance to go out, if unprovided with a special mechanism for relighting them, must (according to the methods which prevail in the mine) either be taken to be relighted to lamp stations, specially placed for that purpose in the fresh air-current; or exchanged for lighted lamps placed ready for substitution at particular points (compare par. No. 84 of this Report).

As to the various details of manipulation of the lamps, including the relighting of extinguished lamps and the examination of the workings for fire-damp, it would appear necessary to include special clauses covering the whole subject in the general regulations issued by the management in the case of every fiery mine. Here, too, the rules as to the maintainance and repair of the lamps in so far as they concern the miners, most conveniently find their place.

3.—Use of Explosives.

135.—Suggested Suppression of Shot-firing.—There is no doubt whatever, that, in the presence of fire-damp—and particularly when it is supplemented by coal-dust—shot-firing is always a risky undertaking. A regulation (which would be strictly enforced and would extend to all fiery mines) prohibiting this practice altogether would certainly eliminate the chances of occurrence of a vast number of explosions; but technical and economic reasons can be brought into the field against a general prohibition of that kind.‡

* Compare Dr. Krelscher, "Preliminary Report of the British Royal Commission on Accidents in Mines," *op. jam cit.*, pages 14-19, and *Final Report*, page 118. † *Appendices*, vol. iii., pages 185-187.

‡ Dr. Krelscher, "Preliminary Report of the British Royal Commission on Accidents in Mines," *op. jam. cit.*, pages 19-21; Mr. Trauzl, *Technical Points of Blasting, Part I.—The Fire damp Question*, Vienna, 1885; *Final Report of the British Royal Commission on Accidents in Mines*, page 51.

As to the technical aspect of the question, we are fain to admit that in most coal-mining districts certain abuses have, in the course of time, crept into the practice of shot-firing; it has been misused in this way that, in actual coal-working, even where the coal is won with comparative ease, shot-firing has more and more tended to kill out the old system of getting, nicking, and holing or kirving. It is quite plain that in many such cases, from the mere point of view of [economic] working of the mine, a tolerably drastic restriction of shot-firing would be extremely desirable, and could indeed be put in force without much difficulty. But a complete prohibition of shot-firing is quite another matter; besides the actual coal-working, it would affect the work of opening and fore-winning in coal and stone. The total abandonment of the enormous mechanical power, which the use of explosives places at our command, would naturally imply a considerable increase in the number of hands that would have to be employed; and, as a consequence, there would most probably result a greater loss of human life from accidents of the ordinary kind. Given certain circumstances, the loss of life thus occasioned would overtop even the losses to be feared from shot-firing and fire-damp explosions. And besides, the operations of opening and fore-winning in very hard coal or very tough stone, if conducted without blasting necessitate an immensely greater expenditure of time, and the length of time constitutes as a rule an additional risk. Yet another danger is that the miner at the working-face is directly exposed to the sudden breaking in of masses of coal and stone, which otherwise, by means of a blasting shot, could be broken down in his absence at a safe distance.

Supposing, however, that the prohibition of shot-firing were to be restricted to the work in the coal—and such was the gist of another proposal laid before the technical scientific section of the Commission*—the measure would be deprived of all practical value, because the operations in coal and stone so dovetail one into the other that it is hard to know where to draw the line of separation. Moreover, it is precisely the work in the stone which very often gives rise to gas or coal-dust explosions, and thus absolute immunity could in no case be assured.

The technical objections are reinforced by those based on economic grounds—first of all, the increase in the cost of production resulting from the diminished productive capacity of each individual workmen.† A series of comparative investigations have been made as to this point; and we greatly fear that so far as the Prussian coal-mining industry is concerned, the complete prohibition of shot-firing in fiery mines would not only render unworkable numerous seams which have hitherto been worked, but would really be equivalent (in the case of a good many collieries which nowadays pay) to entire shutting down. At the very least, a regulation of that kind, which would affect very unequally the different coal-fields and even the different collieries according to the character of their seams—would have most serious consequences (such as unfair handicapping) in the matter of commercial competition.

Taking these difficulties into consideration, the complete prohibition of shot-firing should be regarded only as an extreme measure to be applied to extraordinarily dangerous fiery mines. The majority of the Commission have therefore felt unable to recommend anything like the establishment of a universally prohibitive regulation as to blasting. They were largely swayed by the thought that, apart from the greatest possible restriction of shot-firing, the dangers of that operation may be to a considerable extent, if not entirely, obviated (as was shown by the Commission's Neunkirchen experiments) by discarding the black gunpowder hitherto used in the majority of cases, and substituting for it, duly observing the necessary precautions, the rapid-burning, so-called high explosives.

* *Appendices*, vol. I, page 136.

† Compare *Oesterr. Zeitschr. f. Berg- u. Hüttenwesen*, 1886, No. 17.

136.—*Substitutes for Shot-firing generally.**—Among the innumerable attempts which have been made within the last few decades to discover some practical substitute for ordinary shot-firing, none has met with any striking success. But it has all the same been found possible, without completely doing away with blasting, to dispense with that method of operation in some cases.

Foremost of the proposed substitutes are such methods of working as utilize some other mechanical power instead of blasting-power. Among these should be mentioned getting by means of the ordinary wedge, combined with nicking, and holing or kirving. But this would appear suitable only in actual working, and where the coal (and the accompanying rock) is comparatively soft, or where there are fissures, partings, etc.

It would seem more advantageous to start the operation of wedging by means of boreholes (which should be bored in just the same way as for blasting); and between every two wedges a third wedge is [subsequently] forced in. In this connexion one may especially draw attention to the Godin-Demanet *aiguille-coin* (needle or spring-wedge) and the Dubois & François machine-wedge, wherein the third wedge is driven in from the beginning (either by hand, or by means of the compressed air-engine, which is used to make the boreholes).† We would further mention the Levet quarrying-wedge‡ and the machine wedge,§ wherein the middle wedge is thrust forward by hydraulic pressure (Levet), or the wedge plates are driven apart by means of cast-steel bolts (Walcher).

Although the various wedging contrivances enumerated above are said to have been utilized already for many years with good effect in certain collieries, it is only in a very few cases indeed that they have come into use as a permanent aid in the ordinary course of working. But there is no reason to doubt that in course of time, and when they have been further perfected, these contrivances will be more extensively taken advantage of.

Repeated experiments in the direction of breaking down coal and stone by compression of water or air—either directly into the borehole, or into closed iron cartridges which are intended to burst—have invariably produced negative results owing to the fissures and partings which are always to be found in the strata. For the same reason, the proposed utilization of liquid carbon dioxide appears to us to offer no prospect of success—quite apart from the fact that the introduction of carbon dioxide into the mine is open to the grave objection that it would foul the air to a considerable extent.

The attempt to find in other chemical means an efficient substitute for explosives, has been so far, even less, successful than the attempt to provide a mechanical substitute. The method proposed in England so long ago as 1853 by Sir George Elliot, and revived there recently by Messrs. Smith, Moore, & Co., of using blasting cartridges of freshly burnt lime into connexion with which water is brought,|| is

* Mr. Nasse, "Observations on Apparatus designed in substitution of Shot-firing in Coal-mining," *Zeitsch. f. d. Berg-, Hütten u. Salinen-Wesen im Preuss. Staate*, vol. xvii., B., page 416, et seq.; Mr. A. Habets, "Means of Preventing Fire-damp Explosions and averting their Hurtful Effects," *Revue Universelle des Mines*, series 2, vol. 1., pages 149-152 (*Glückauf*, 1877, No. 9); Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, orig., pages 127-128; Mr. G. Kohler, "Blasting in presence of Fire-damp, and its Substitutes," *Zeitsch. d. Vereines deutsch. Ing.*, 1886, No. 8; *Final Report of the British Royal Commission on Accidents in Mines*, pages 62-65.

† Mr. Ch. Demanet, *The Working of Coal-mines*, German translation by Mr. C. Leybold (Brunswick), 1886, pages 217-220; Mr. A. Habets, Amsterdam Exhibition, 1883, *Documents and Reports of the Members of the Jury*, Brussels, 1883, pages 55-58.

‡ *Zeitschr. f. d. Berg-, Hütten u. Salinen-Wesen im Preuss. Staate*, vol. xxx., B., pages 230-231.

§ Mr. Von Wurzbach, "Coal-breaking Apparatus (Walcher Patent)," *Oesterr. Zeitschr. f. Berg-u. Hüttenwesen*, 1886, No. 18, and 1887, No. 14.

|| Mr. Paget Mosley, Lecture to the Spring Meeting (1882) of the Iron and Steel Institute, compare *Glückauf*, 1882, No. 64.

shown, by numerous experiments conducted in almost every coal district, to act too slowly and too feebly to be available for general use. More especially is it impracticable at the actual working-face, that is at the very point where it is of the greatest importance to have some substitute for blasting-powder. The same defect is observable in Mr. B. Kosmann's blasting cartridges* (which evolve hydrogen gas from sulphuric acid and zinc dust), and in Messrs. R. and Ch. Steinau's cartridges† (filled with lime which, in contact with water, causes a flask filled with sulphuric acid and a flask filled with water to burst, and is then supposed to produce the required effect by the resulting evolution of steam); and the objection attaches to Mr Edison's electric blasting-process,‡ wherein water contained in a sealed glass tube is decomposed by the electric current. For the rest, these processes appear somewhat dangerous, on account of the extreme inflammability of hydrogen gas.

137.—*Substitution of High Explosives for Black Gunpowder.*—As we have already set forth in another portion of this Report (compare par. No. 90), the Commission, bearing in mind their exhaustive experiments, have arrived at the conclusion that the dangers attendant on blasting in fiery mines may be notably diminished, nay, perhaps completely obviated, if, instead of using the slowly burning black gunpowder which has been hitherto made use of in most cases, only quickly igniting, so-called high explosives were employed. The Commission therefore propose (see Art. 19 of the "Principles") to restrict the prohibition of blasting simply to black gunpowder. On the other hand, they propose to allow the use of high explosives in coal and stone indifferently, so long as there is at any point of the district concerned no permanent accumulation of fire-damp present, that is no accumulation easily discernible by means of the safety-lamp.

At the present moment, the Commission do not deem it advisable to recommend any particular high explosive in preference to any other. It is perfectly evident that more extended practical experience is necessary, and that time must be left to the inventor and the manufacturer of explosives, so that by means of new inventions or improved methods of manufacture they may be enabled to comply more fully with the requirements of the coal-mining industry.

138.—*Precautionary Measures in Blasting Operations.*—If on the one hand there is no room for doubt that in course of time blasting operations in fiery mines will have to be considerably restricted in one way or another; it is on the other hand equally beyond dispute that the precautionary regulations in the matter of blasting (so far as it is allowed) directed against the possibility of ignition of fire-damp and coal-dust should be made very much more severe.

The first principle which must be observed unflinchingly is that no blasting operations shall be allowed under any circumstances to take place if and so long as fire-damp is found to occur at the particular point in quantity recognizable by the safety-lamp. Therefore, before any shot is fired, it should be ascertained by means of a careful search that neither in the immediate neighbourhood of the borehole nor within a radius of 10 metres (32½ feet) is any accumulation of fire-damp present (Art. 19 of the "Principles").

In dry, dusty mines, where the coal is particularly prone to make dust, care should be taken (at least in opening and fore-winning) to remove any coal-dust lying about within at least the same radius as above mentioned, or to render it harmless by plentiful watering, before firing a shot.

The decision whether both these requirements have been fully complied with and

* German Imperial Patent, 34665; *Glückauf*, 1886, No. 16.

† German Imperial Patent, 38000; *Berg-, u. Hüttenmännische Zeitung*, 1887, No. 21.

‡ Compare *Berg-, u. Hüttenmännische Zeitung*, 1886, No. 5, and *Comptes rendus de la Société de l'Industrie Minérale*, 1886, pages 92-99.

whether therefore the shot may be fired, should in no case rest with the workman but either with the responsible overman, or better still with the superintending official whom it may concern or with a person who is especially entrusted with that task (fireman). In fact it would be advisable that the entire operation of blasting, including the stemming of the shots, should be carried out by specially appointed, trustworthy persons who would take no part in other labour at the working-face; and in such wise that the other persons employed in the mine could be strictly forbidden to carry about with them or use explosives, firing or lighting-material of any kind, etc.

As to the actual conduct of the operations of blasting, in addition to the ordinary precautionary measures, the following rules should be observed:—

- 1.—Shots in the roof are to be avoided wherever possible.
- 2.—In order to avoid blown out shots, the bore-holes should not be made too long, (especially in fast working-places), and its effect should be as much as possible enhanced by holing or kirving before firing it. Care must be taken not to overload the shot.
- 3.—The stemming of shots with coal should be forbidden (Art. 19 of the "Principles").
With shattering explosives the use of water-cartridges is advisable (compare par. No. 91 of this Report).
- 4.—In shot-firing only such igniting-materials should be used as burn without flame (compare par. No. 89 of this Report).
- 5.—If several shots are to be fired at the same place, they are (always excepting cases of ignition by electricity) not to be fired simultaneously, but singly, one after another; and that only after the responsible persons have every time satisfied themselves that no fire-damp is present.
- 6.—Shot-firing should, as far as possible, take place at a time when very few persons are at work in the immediate neighbourhood of the firing-point or indeed present in the pit at all. Where it is a question of bringing-down the stone or neighbouring rock, shot-firing should never be allowed during the haulage-shift.

All such special regulations, as well as the general provisions with regard to permissibility or restriction of shot-firing, are properly included in the ordinary working regulations (precautionary rules), which must be issued by the management of every individual fiery mine.

4.—With regard to Coal-dust.

139.—*Damping and Removal of the Coal-dust.*—We have already (compare par. No. 78 of this Report) laid stress on the fact that the precautionary measures against the dangers which arise from coal-dust consist partly in scrupulous avoidance of the deposition and accumulation of dry dust in the pit-workings, and partly in guarding against its being swept up in a series of whirlwinds as a result of shot-firing, etc.

As to the first point, in dry mines where the coal produces much fine dust, there only remains the resource of regular and abundant watering. At the very least, the main haulage-ways (as already recommended by the French Fire-damp Commission in accordance with Mr. Galloway's method)* should be kept continually damp. The British Inspectors of Mines, Messrs. W. N. and J. B. Atkinson,† consider that the

* *Principles to be Consulted in Working Fiery Mines*, section 39.

† Messrs. W. N. and J. B. Atkinson, *Explosions in Coal-mines*, 1886; Mr. Nasse, "Remarks on Coal-dust Explosions," *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxiv., pages 191-200.

application of the method should be still further extended, so that, besides wetting the dust lying about on the floor of the drift as thoroughly as possible, and then causing it to be removed from the galleries, the extremely dangerous fine dust which clings to wall and roof and timbering, should be completely washed off by means of a water-hose. Worthy of recognition, too, is their additional proposal, that those drifts which form the arteries of communication between different districts should be walled with masonry for considerable lengths where suitable, and then always kept wet and free from dust, preventing thereby the further spread of any dust-explosion which may arise.

Concurrently with the process of keeping the galleries damp, in places where shot-firing is allowed, the utmost care should be taken (immediately before firing a shot) to similarly render innocuous the dust which is lying about in the near neighbourhood of the firing-place (compare par. No. 138 of this Report). It is hardly necessary to point out the extreme importance of fulfilling conscientiously the last-mentioned duty (also first recommended by Mr. Galloway); and in those cases where it is found impossible to carry out that procedure in its entirety, it will be best to forbid any shot-firing whatever.

Though one may admit as a general proposition that there are considerable difficulties in properly damping and thoroughly getting rid of coal-dust even in the haulage-ways, and still more in the actual working-places of a dry mine, still these difficulties have been shown by experience to be of such a nature that a little perseverance will overcome them. At any rate, watering carried on as a regular practice must have this result, that the coal-dust which is present will be thoroughly saturated, and thereby the inflammability of the dust will be very considerably diminished.

5.—Other Measures.

140.—*Introduction of finely divided Water or Steam into the Pit.*—Mr. J. d'Andrimont* and after him Mr. R. Wabner† proposed to introduce finely divided water or steam into the pit, concurrently with the ventilating current, for the purpose (on the one hand) of making the fire-damp present less easily inflammable, and for a similar purpose, as regards coal-dust, by saturating the dust with water. But these proposals are met with the practical objection that it is difficult to bring water in sufficient quantity, for the aim in view, to the galleries and working-places where it is needed, and that it is particularly difficult to bring it to the working-face. Experiments which have been carried out in connexion with this matter, *e.g.*, at the Heinrich shaft, Planitz, Kingdom of Saxony,§ and at the Neu-Iserlohn pit, Langendreer, Westphalia,|| have demonstrated the absolute uselessness of the introduction of water-vapour (steam). There is moreover another serious objection to the last-named method, namely, that the heating of the downcast ventilating current might not only have hurtful consequences as regards the actual ventilation of the mine, but also on the health of the people employed therein, and the security of the galleries (loosening of blocks of strata). If the attempt were made to lead the steam by special conduits to each separate level (as is done with fresh air in the special [separate] ventilation system), the evils to which we have just referred would evidently be greatly enhanced.

* Belgian Fire-damp Commission, *Report, Proceedings at Meetings, and Documents*, 1880, page 55.

† Mr. R. Wabner, "The Prevention of Ignition of Fire-damp in Coal-mines by means of Water-vapour or finely divided Water," *Berg-, u. Hüttenmännische Zeitung*, 1882, No. 24, also 1885, Nos. 40 and 41.

§ Mr. B. Otto, *Fire-damp*, etc., Berlin, 1886, page 94.

|| *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxv., page 261.

141.—The Poetsch Freezing Process.—Mr. F. H. Poetsch believes that the ignition of fire-damp may be rendered impossible by means of the production of extreme cold. The patent which he has taken out* for an "apparatus to prevent the ignition of fire-damp by cooling down the gas," includes the production of cold air above bank in a spiral channel with masonry walls (communicating by means of conduits with the pit); this is done by squirting a solution of common salt through the perforations of a tube, along which the air is made to travel. According to a supplementary patent, a liquid or lye, artificially cooled much below freezing-point, is to be rained into the shaft; and besides, in the pit itself, by means of a portable spraying-apparatus the freezing-cold solution is to be kept in continual circulation, and thus the process of cooling-down may be applied to the remotest points of the workings.

There is, of course, no doubt at all that the inflammability of combustible gases decreases with diminishing temperature. But if Mr. Poetsch, in the justificatory preamble of his patent (application) proceeds on the assumption that pit-gas ceases to be inflammable at a temperature of about + 4 degs. C., he is assuming what is not the fact. If we admit that mixtures containing 6 per cent. of marsh gas are still inflammable at the average temperature of 14 degs. C., then, calculating the decrease of inflammability in relation to lowering of temperature, mixtures containing 7 per cent. CH_4 will still be inflammable at - 100 C., and 10 per cent. mixtures even below - 400 degs. C. And in any case, at the temperature of + 4 degs. C., gaseous mixtures containing more than 6.1 per cent. of methane can undoubtedly be ignited.

The conclusion is that the Poetsch freezing process will in no way prevent the ignition of fire-damp, although it may serve to lower the temperature of the pit, and that with a good deal of difficulty in very extensive workings.

142.—Explosion Doors.—In order to restrict such gas or dust-explosions as may take place within the narrowest possible limits, various kinds of safety-doors have been experimented with in France.† Mr. Verpillieux puts two very strong doors, which open in opposite directions, at a very short distance from one another; they are usually kept open by very light springs, etc., but as soon as an explosion occurs one of the doors closes. Messrs. Clermont and Mathet made use of doors woven of several superposed layers of wire-netting; these also closed immediately on the occurrence of an explosion, and were presumed to at least hold back the explosion-flame. Mr. Mallard proposed movable doors, which immediately after the ignition of a blasting-shot would bar the entry to the working-places beyond the ordinary range of action of the shot. This last proposal has recently been taken up again in Germany.‡ But whether with arrangements of that kind any sufficiently satisfactory result is likely to be attained appears to us extremely doubtful.

IV.—LIFE-SAVING AFTER AN EXPLOSION.

143.—Life-saving Apparatus.—Among the innumerable appliances intended to enable a rescuing party to press forward and accomplish their task amid the after-damp which follows on an explosion,§ the various respirators (Brasse, Loeb, etc.) are

* German Imperial Patent, 27312, May 25th, 1883; Review of the Patent Records by Mr. F. H. Poetsch, Magdeburg, 1896, Nos. VII., VIII.

† Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, pages 126, 195-197.

‡ *Glückauf*, 1885, No. 14; *Oesterr. Zeitschr. f. Berg-, u. Hüttenwesen*, 1886, Nos. 25 and 28.

§ Mr. A. Habets, "Means of Preventing Fire-damp Explosions and Averting their Hurtful Effects," *Revue Universelle des Mines*, series 2, vol. i., pages 143-152; *Glückauf*, 1877, No. 12; Mr. Haton de la Goupillière, *Report of the French Fire-damp Commission*, pages 260-266; Dr. Serio, *Treatise on Mining*, 4th ed., 1884, vol. II., pages 473-494; Dr. Krelscher, "On Life-saving Apparatus in Mining, and especially the Fleuss Apparatus," *Jahrb. f. d. Berg-, u. Hüttenwesen im Königr. Sachsen*, 1886, pages 146-162.

only trustworthy for short distances, while the Galibert air-bag only lasts for a short time; and, finally, the Rouquayrol-Denayrouze air-hose, which is supplied from a fixed air-pump (pneumatic machine), is a hindrance to the advance of the rescuers, because they have to drag the hose along with them. So far, for rescuing purposes, the Von Bremen (Rouquayrol-Denayrouze) knapsack-apparatus with compressed air (and spare cylinders containing an extra provision of air) appears to have worked more satisfactorily in practice than any other.* Then, too, the recently introduced breathing-apparatus of Messrs. Fleuss, Duff, & Co.,† which continually renews and makes the foul air breathable by elimination of carbon dioxide and absorption of fresh oxygen, should render valuable service when certain considerable improvements shall have been made in it.‡ The last-mentioned apparatus, which is remodelled on a combination of two older appliances, those of Messrs. Schulz and Schwann, appears moreover to correspond pretty closely to the apparatus brought out by Mr. Regnard at the instance of the French Fire-damp Commission.§

If it be true that, on the whole, appliances of that kind will need to be used only in very rare cases, we should, nevertheless, urgently recommend the holding in readiness in all fiery mines of one or other of such appliances. Moreover, as many as possible of the officials and pitmen should be frequently instructed and exercised in the use of them, as they might well be of considerable assistance in the event of a conflagration in the pit.

144.—Help for the Injured.—The measures which have to be taken immediately on the occurrence of a fire-damp explosion, and chief of all the operations directed to the rescue of the victims, depend largely on the circumstances of each particular case. With regard to the preliminary assistance to be rendered to the victims of a disaster, very great stress has been for many years, and rightly, laid in all mining districts in Prussia, on the necessity for every mining official whom it may concern to be thoroughly instructed in the treatment of those persons who may be found wounded or insensible (stupefied by gases). They are to learn this at the mining schools, and it is a knowledge which must be moreover extended to as large a number as possible of the workpeople employed in the mine. Thus also it is the practice nearly everywhere to have medical, surgical, and other appliances ready to hand at the pit shaft or in the immediate neighbourhood. As an example deserving universal attention we may point, in this connexion, to the extraordinarily successful results obtained after the fire-damp explosion at the Camphausen pit (Saarbrück), on March 18th, 1885, with the treatment of a great number of men in a comatose condition by immediate application of the cold-water spray in a warm bath.||

* Messrs. L. von Bremen & Co., *Respiratory and Lighting Apparatus for Mines*, Kiel, 1873; *idd.*, *Portable High pressure Breathing and Lighting Apparatus*, Kiel, 1876; Mr. Hasslacher, "The Rouquayrol-Denayrouze Diving, Breathing, and Lighting Apparatus, and its use in Mining Industry," *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxii., B., pages 1-17; Mr. Joh. Mayer, "Remarks on the Fire-damp Explosion in the Wilhelm Shaft of the Emperor Ferdinand-Northern Railway in Pölnisch-Ostrau, the Pit Fire arising from it, and the Operations of Extinction, especially with Mr. L. von Bremen's Breathing Apparatus," *Oesterr. Zeitschr. f. Berg-, u. Hüttenwesen*, 1885, Nos. 33-50.

† "The Fleuss Life-saving Apparatus," *Iron*, 1884, page 87; German Imperial Patent, 16343, and *Glückauf*, 1883, No. 36; Dr. Kreischer, "On Life-saving Apparatus *op. jam cit.*", pages 154-162.

‡ *Zeitschr. f. d. Berg-, Hütten- u. Salinen-Wesen im Preuss. Staate*, vol. xxxiv., B., pages 272-275.

§ *Final Report of the French Fire-damp Commission*, German translation, *op. jam cit.*, page 298.

|| *Annual Report of the Saarbrück Miners' Union for 1885*, pages 31-33; *Glückauf*, 1886, No. 99.

THIRD PART.

PRACTICALLY APPLICABLE CONCLUSIONS AND SUGGESTIONS.

1.—*From the Technical Point of View.*

145.—The Commission have thought fit to draw up a concise summary of their opinions, embodying the technically important results of their labours, and reciting all the preventive measures to be taken against fire-damp, which have been hitherto a matter of dispute or at least insufficiently adopted; and this in the following terms:—

PRINCIPLES TO BE OBSERVED IN FIERY MINES.

I.—GENERAL REGULATIONS.

Art. 1.—Those mines are to be regarded as fiery wherein during the last two years fire-damp has been known to occur.

Where in respect of haulage and ventilation the mine is divided into several independent working districts, each of these districts is considered as a distinct mine.

Art. 2.—In all fiery mines, there must be, at the very least two outlets at the surface separated from one another by a sufficiently solid wall of rock or stone. Of these two openings, one should serve as a downcast, the other as an upcast air-way.

Temporary exceptions to this rule are nevertheless permissible.

II.—VENTILATION.

Art. 3.—In every fiery mine, a regular system of ventilation must be arranged in such a manner, that accumulations of fire-damp may be rendered practically impossible (under ordinary conditions) in the working-places; and every portion of the mine at the working-places or in the galleries shall be at all times in a fit condition for the conduct of mining operations and the traffic of the mine.

Extensive workings should be subdivided for ventilation purposes into several independent sections.

The driving of separate airways appears desirable.

Art. 4.—Ventilation conducted exclusively by natural means is not permissible. Nor can the exclusive provision of ventilation by means of the chimneys connected with the boilers be allowed.

The use of ventilation-furnaces is allowable only in those collieries where the conditions are such as to assure continuous supply of the furnace with fresh air, and the provision of an easy and secure means of retreat for the furnaceman (in case of need); and where, moreover, there is no possibility of ignition of the pit gas by the furnace gases.

Open fire-lamps (fire-kibbles) are forbidden.

Art. 5.—The volume of fresh air per minute, which should be supplied in a fiery mine must in each independent ventilation-district amount to 1·5 cubic metres (52·95 cubic feet) per ton of the average daily coal output. If this volume be inadequate to reduce the gaseous content of the return air-current to 1·5 per cent., it must be correspondingly increased. Where, on the other hand, the total percentage of methane and carbon dioxide in that current does not unitedly amount to 1·5, a reduction of the fresh air-supply to 1 cubic metre (35·31 cubic feet) per ton of daily coal output may be regarded as admissible.

In all cases, however, the volume of fresh air must amount to at least 2 cubic metres (7.062 cubic feet) per head of the maximum number of workmen employed below ground in the course of one shift. In these calculations, a horse is reckoned as equivalent to four men.

Art. 6.—The motors which are intended to produce the ventilation are to be made and kept of such power that the prescribed minimum air-supply may at any moment, and without delay be increased by 25 per cent.

The use of a self-registering check apparatus in connexion with ventilators is urgently recommended.

Art. 7.—It appears absolutely indispensable (at least in the case of newly driven levels and shafts) to make the sectional area of the main airways not less than 8 square metres (32.3 square feet).

But the dimensions of the main and other airways are to be so contrived that with sufficient ventilation of the workings the air-velocity per minute shall not exceed 240 metres (787 feet) in the downcast, and 360 metres (1,181 feet) in the return air-current. As a general rule, it is recommended that much lower velocities be used by means of enlarged sectional areas and splitting of the current.

The accessory use of ventilation-boreholes may be sometimes resorted to.

Art. 8.—The ventilation must be so arranged, both as a whole and in detail, that the fresh air is led from the surface by the shortest possible route downward to the working-levels; but that thereafter the separate air-currents in the various working-districts shall follow an invariably ascending course.

Downward ventilation of workings in active use—with the exception of headings driven to the rise, where such ventilation cannot of course be dispensed with—is only allowable as an exception in consideration of the circumstances of the particular case, and subject to an abundant supply of fresh air and the provision of trustworthy bratticing.

There appears to be no objection on the score of danger to leading downwards of air-currents which are not intended to be made further use of.

Art. 9.—The number of working-places to be supplied from one and the same air-current must not exceed that which will allow of the air reaching the remotest of those places in a state of sufficient coolness and purity.

A man-fouled air-current should be brought to the upcast by the shortest possible course without traversing any more of the workings which are in active use.

Art. 10.—Particular attention should be paid to the transmission of the fresh air up to the very working-face. In no case should the ventilation of level-places be simply dependent on diffusion for a distance of more than 20 metres (65 feet).

Places to the rise must not be driven without special ventilation; in galleries driven to the dip this need only be arranged when they are more than 15 metres (49.2 feet) in length.

Shafts, crossouts, and headways (in so far as they are not driven by parallel working) may only be driven with the help of air-brattices, air-tubes or air-conduits of adequate sectional area.

The inclination of bordways should not exceed 1 in 100.

It is advisable to ventilate independently such places as particularly need air by the system of compressed air and insufflation-conduits, or by the Körtling injector or such other suitable apparatus.

The regulation that hand-power ventilators should always be placed in the fresh air-current must be strictly enforced.

All such air-drifts and air-stentings as may no longer be used for purposes of ventilation must be barred off by a permanently airtight partition.

Art. 11.—Ventilation-doors must close automatically, and at those points where

hermetical closure is desirable, or where in consequence of the conditions of working in the mine considerable traffic takes place, the doors must be at least double, and placed at such a distance from one another that one of them is always closed.

Ventilation-doors which have become superfluous are to be removed from their hinges.

Art. 12.—No alterations with respect to the regulation of the ventilation may be undertaken without special instructions from the superintending official whose concern it is.

Any accident or damage which may happen to air-brattices and air-doors, and any irregularity in the ventilation must be in all cases immediately reported to the superintending official.

Art. 13.—Disused workings must be barred off in a clearly recognizable manner, and entry into them must be forbidden.

Art. 14.—The outflow of fire-damp from the goaf must be prevented by closing up or ventilating the latter.

When the workings approach old workings, or such spots where accumulations of fire-damp may be expected, preliminary borings should be made.

Art. 15.—Every place—if the miners are not loosed at the working-face itself—must be carefully examined for the occurrence of fire-damp before the new shift enter therein to start work.

Art. 16.—When ventilation is stopped or is greatly disturbed, the workmen must be withdrawn as quickly as possible from the dangerous portions of the mine, and men must not be allowed to return therein until a preliminary examination has shown that mining operations may be conducted with due security.

So soon as signs of danger (such as threatening accumulations of fire-damp) are discerned at any particular point in the workings, the workmen must fence off the dangerous district, evacuate it, inform their comrades of the state of affairs, and report thereon to the first mining official whom they can meet.

Art. 17.—Fore-winning and actual winning, with the exception of cases where downward ventilation is specially allowed, must not take place in any district of the workings, until an airway has been cut through to the [next] upper level.

Art. 18.—In all fiery mines care must be taken to ensure constant and trustworthy supervision of the ventilation as a whole and in all its details; if necessary, officials must be specially appointed for that duty alone.

III.—SHOT-FIRING.

Art. 19.—In all fiery mines, it is hereby forbidden to conduct blasting operations which involve the use of black gunpowder or such other slowly detonating explosives. The use of dynamite, and other quickly-detonating explosives which behave similarly with regard to coal-dust, is alone permissible.

Even with dynamite, etc., blasting operations are not allowable in those districts (of the mine) where at any working-place under ordinary circumstances such accumulations of fire-damp as are easily recognizable by means of the safety-lamp (3 per cent. of fire-damp) cannot be prevented.

In every case, before each shot is fired the responsible official must ascertain that no accumulations of fire-damp are present within a radius of 10 metres (32½ feet).

Stemming of shots with coal should be forbidden.

IV.—LIGHTING.

Art. 20.—In no fiery mine is the use of naked lights below ground permissible. Only safety-lamps and electric incandescent lamps may be used

But within the downcast fresh air-current in the shafts and at the pit-eye naked lights may be made use of. The use of them in upcast shafts is allowable in certain special cases.

Art. 21.—Safety-lamps should fulfil the following requirements :—

- (a) The enclosure of the combustion-chamber should be so arranged and maintained that at no point may the combustion-chamber be in communication with the outside air by an opening of larger area than 0·0004 square inch (0·25 square millimetre).
- (b) The wire-gauze must be evenly woven of wire of, say, 0·37 to 0·42 millimetre fineness (·0146 to ·0165 inch), and the sectional area of each portion of the mesh should never be greater than 0·25 square millimetre (0·0004 square inch).
- (c) Every safety-lamp must have an illuminating power of at least 60 per cent. of one normal candle-power. It is, however, permissible in searching the workings for fire-damp to make use of lamps of lower illuminating power.
- (d) Every safety-lamp must be so made that its component parts fit tightly and intimately together.
- (e) The lamp must be provided with a lock, of such character as to enable the point, whether it has been tampered with or not, to be easily ascertained and checked, and such as to secure the perfect interlocking of the component parts.

Art. 22.—The following further recommendations are made with regard to the fitting of safety-lamps :—

- (a) The air necessary for combustion should, in lamps provided with glass cylinders, be led in from above, downward.
- (b) The glass-cylinder should possess a perfectly even wall-thickness throughout, and should consist of glass of the best quality and most carefully annealed. Its edges must be ground exactly horizontal and at right angles to the axis of the lamp. It should measure in height 54 to 60 millimetres (2·12 to 2·36 inches), in average diameter 40 to 50 millimetres (1·57 to 2 inches), and in wall-thickness 6 to 8 millimetres (about 0·24 to 0·32 inch).
- (c) The wire-gauze should measure in height between 95 and 105 millimetres (3·74 to 4·13 inches). It should not be narrower in its lower portion than the glass-cylinder, and its upward tapering should not be greater than 10 millimetres (0·39 inch).

Art. 23.—The safety-lamps are to be delivered to the workmen by the colliery management ; and it will be moreover the duty of the latter to provide for the storage and repair of the lamps.

It is advisable to number the lamps consecutively, and to always give the same lamp to the same man.

V.—SPECIAL REGULATIONS.

Art. 24.—In all fiery mines, the management shall issue special regulations, which shall have been previously submitted to the Government authorities for their approval. These regulations would apply to :—

- (1) The superintendence of the ventilation, the regular examination of the workings for fire-damp, and the measures to be taken in the event of the latter being found to occur.
- (2) Superintendence of, and precautionary measures connected with shot-firing, in so far as that is allowed.
- (3) Manipulation of the safety-lamps.

(4) Regular measurements of—

- (a) The quantity of air.
- (b) Gaseous content (deleterious gases) of the air.
- (c) Atmospheric pressure.
- (d) Temperature.

146.—The “Principles” set forth above are by no means intended to represent an exhaustive summary of the fire-damp question from the point of view of mines regulations; but, in pursuance of the task with which the Commission had been entrusted, they at least form a *corpus* of technical opinion on the main points which claim one's attention in connexion with that problem. At all events, the clauses have been so drawn up that they may be used as the basis of such mines regulations as may be issued.

The different subjects dealt with in the “Principles” have received fairly adequate treatment in the corresponding technical sections of the present Report, and it now only remains to advert briefly to some more general matters.

In order to define more exactly the proper use of the “Principles,” the Commission considered it necessary to start (Art. 1) with an accurate explanation of the term *fiery mine*. The actual occurrence of fire-damp was held to be the first condition of the term—so far as the gas is discernible with the ordinary safety-lamp hitherto in use, and without any regard to the fact whether the occurrence is isolated or general and constant. The Commission premised that so soon as gases in a pit are recognizable with the safety-lamp, a certain amount of danger must be necessarily inferred, and therefore special precautionary measures will have to be taken. Nevertheless, in order to avoid unnecessary interference with mining operations in such districts as are free from gas, in extensive workings where there are only local outbursts of fire-damp, each working-district should, for purposes of haulage and ventilation, be regarded as practically a pit by itself. On the other hand, we find it impossible to subscribe to a more far-reaching suggestion, namely in every fiery mine to release from observance of the strict letter of the regulations all such portions of the workings (in particular seams or particular districts) as have for a long period of time been free from fire-damp. And that because, in such a mine, a mixed system would come into play which might give rise to the most serious dangers.

As regards the further question whether a mine wherein fire-damp has once occurred is to be always thereafter regarded as a fiery mine; or whether, if the occurrence be not renewed within a certain period, that mine is once more to be reckoned among the mines free from fire-damp, the Commission have thought fit to declare themselves in favour of the latter view, inasmuch as the prescribed period of observation is to extend over an amply sufficient interval of time, namely two years. Proposals to reduce the probationary period to one year or even six months were declined, because it appeared to the Commission that the interval was too short to make it certain in all cases that the pit had been so completely freed from gas as to render the observance of strict regulations no longer indispensable.

If the Commission hold that the actual occurrence of fire-damp sufficiently warrants the designation of the mine as a fiery mine, this naturally implies that in all collieries without exception a regular examination for fire-damp should be strictly enforced by bye-laws, and the very first occurrence should be at once reported to the Government mining authorities.

In connexion with the definition of the term *fiery mines* it had been proposed to subdivide these into different categories (somewhat after the fashion of the Belgian General Mines Regulations of April 28th, 1884) according to the extent of

their presumed perilousness; and then to graduate the regulations as to amount of ventilation, permissibility of shot-firing, etc., according to each one of such categories. This proposal has not been accepted by the Commission, because they think that a really useful classification of that kind is impracticable in the Prussian coal-mining industry—it matters little whether that classification be based on the gaseous content of the return air-currents, on the frequency, the special character or extent of the explosions which have occurred. It seemed to them advisable rather so to draft the general principles as to make these correspond to the average conditions of fiery mines, and then according to the special circumstances of each case the regulations based on these principles may be relaxed or the reverse.

With regard to the extent of ground covered by the "Principles," the Commission have thought proper to limit themselves to a summary of merely the main points. They are, moreover, of opinion that in a similar way the mines regulations to be issued by the Government authorities whom it may concern should comprise only general rules—and that details should be reserved for the special regulations which the management of every fiery mine has to draw up and submit to the approval of the authorities. This course of procedure was inaugurated with conspicuous success by the General Mines Regulations issued on November 8th, 1867, by the Royal Mining Bureau at Bonn, for the district falling within the area of administration of that bureau. Naturally, the same influence, from the legal and penal point of view, must be attributed to the special colliery regulations as to a decree issued direct by the Government authorities.

As to subject-matter and form of such special regulations, the first-named is defined in Art. 24. With regard to the form, it would be advisable to draft the instructions concisely as such, without attempting comments or explanations, and those rules which affect the colliery management or particular colliery officials should be separated as distinctly as possible from rules affecting the workmen. A point of no small practical importance, when one considers the frequent migration of workmen from one colliery to another, is the drafting of (as far as may be) identical regulations for all the several collieries of the same district or of neighbouring districts, so as to avoid on the part of the miner any confusion between particular regulations—a confusion which, under certain circumstances, might constitute a source of positive danger.

2.—*From the Legal and Cognate Points of View.*

147.—*Increased Severity of the Existing Judicial and Penal Regulations.*—Much as we are pleased to note here that the journeys of inspection and the labours of the Commission have already borne good fruit, in that they have led to vast improvements being made of late years (in all the Prussian coal-mining districts) in the matter of preventive measures against fire-damp explosions—and probably these improvements will be extended yet further by colliery managers in an enlightened spirit of self-interest—yet we think there is no doubt that the mines regulations as by law enacted, need in many respects modification in the sense of greater severity and completeness. In this connexion the "Principles" drafted by the Commission might well serve as a basis conveniently applicable to most cases. Moreover, good effects might be looked for from special (precautionary) regulations, picked out from among those proposed, to be drafted for every fiery mine by the colliery management.

But at the same time as a new system of mines regulations, a corollary is indispensable in the shape of stricter penal enactments; these will, most especially so far as the workpeople are concerned, give to the regulations that sanction which is necessary to ensure their being properly carried out. The statistics prove (compare

par. No. 31 of this Report) that the overwhelmingly greater number of fire-damp explosions in Prussian collieries are due to carelessness or imprudence, carelessness or imprudence which are in the first place translated into defiance of some prohibition enacted by the mining authorities or the colliery management, or into negligence to observe some provision prescribed by the same authorities. Although the culprit may in some cases, where men have been injured or killed—expiate his sin in gaol; in the many cases where no really disastrous consequences have ensued, he is, in accordance with the present system of jurisprudence, let off with a paltry fine. This latter punishment, of course, counts for nothing with the workmen, when weighed against the advantages in time and money which they may sometimes secure by disobeying the regulations.

The Commission therefore came to the conclusion that the only drastic, the only effectual, remedy for this state of things would be found in fresh legislation. But they were of opinion that a special Act (such as had been often proposed) would hardly be of so much service as a modification or expansion of that portion of the German Penal Code which treats of "Crimes and Misdemeanours affecting the General Welfare" (Part II., Section 26 in the edition of February 26th, 1876).

And in this respect also, under certain circumstances, Arts. 306-311, on "Incendiarism (arson)" might be reconsidered. For instance, in Art. 311,* after the words, "or by other explosive substances," one might insert, "or by ignition of fire-damp in mines." In this way, neglect or defiance of the regulations concerning the lighting of the pit or shot-firing would be subject to the same punishment (involving imprisonment in gaol or in a house of correction) as deliberate arson or arson by negligence.

And then most especially should Art. 321† be supplemented by the following clause, in addition to those which already deal with the misdemeanours connected with mining, after the words "ascent or descent of the workpeople":—"or whosoever disturbs or hinders the ventilation or in fiery mines (legal enactments notwithstanding) makes use of naked lights, or sets fire to a shot, or ignites a flame, or opens a safety-lamp."

If it were possible at the next opportunity for revision of the Penal Code to have these supplementary clauses incorporated therein, we have no doubt that they would constitute an extremely effectual check to the recklessness and levity which often result in bringing about a fire-damp explosion.

148.—*Extension of a Better Understanding of the Precautionary Regulations among the Workmen in the Pit.*—We know by experience that the cause of a large proportion of the cases of defiance or negligence of the precautionary regulations in a colliery lies in an insufficient comprehension of those regulations and in the inability to grasp the full extent of the consequences which such defiance or negligence surely entails. The ordinary method of publication of the regulations by reading them out to the workmen and hanging copies up at the colliery (as enacted by Art. 200 of the General Mining Act of June 24th, 1865) would of itself seem hardly sufficient. The Commission are of opinion that, in addition to the ordinary publication, a concise abstract of the points which have to be observed by the workmen themselves

* Art. 311 reads: "The total or partial destruction of property by the use of gunpowder or other explosive substances is to be considered equivalent to the setting on fire of the said property."

† Art. 321.—Whosoever purposely destroys or damages water-conduits, sluices, weirs, dams, or other hydraulic appliances, or bridges, ferries, roads, or parapets, or the mining appliances for retention of water, for ventilation, or for ascent or descent of the workpeople; or whosoever disturbs the navigable channel in rivers, streams, or canals, and through any one of these misdemeanours endangers the life or health of other persons, shall be punished with not less than three months' imprisonment. If through any one of the above enumerated misdemeanours serious bodily harm has been caused to any person, the sentence may be increased up to five years' penal servitude; and if the death of a person has been caused thereby, the sentence shall be not less than five years' penal servitude.

should be (as widely as possible) distributed among the miners—much in the same way, perhaps, as is done with the “working orders” and “benefit-society circulars”—by handing a printed copy to every man. It would be well to refresh the memories of the miners as regards this abstract by reading it out to them from time to time, and wherever and whenever necessary by explaining more fully particular points in it.

A matter of no less importance is to always strive by means of appropriately instructive writings or lectures, to spread among the officials and among the miners correct views and ideas as to the conditions which mainly influence mining. In particular would it be advisable in this way to make the miners arrive at a clear understanding of the character and dangers of fire-damp, and of the precautionary and protective measures which they may use as weapons to fight it with. As a kind of sketch-model on which local educational broadsheets might well be based, Commissioner Harz has prepared, at the request of his colleagues, a “Fire-damp Catechism for Miners,” drafted in the form of a series of questions and appropriate answers.*

Finally, it needs no words from us to emphasize the fact that all progress in the matter of general education and technical instruction of the miners will assuredly be of enormous service in the matters to which we have just referred, and therefore every step in the direction of such progress (whether the initiative comes from the colliery managers or from the Government authorities matters little) should be hailed with acclamation.

Berlin, July, 1887.

* *Appendices*, vol. I., pages 150-153.

III.—NOTES OF PAPERS ON THE WORKING OF MINES, METALLURGY, ETC., FROM THE TRANSACTIONS OF FOREIGN SOCIETIES AND FOREIGN PUBLICATIONS.

THE ASSAYING OF ANTIMONY ORES.

Note sur l'Essai des Minerais d'Antimoine. By AD. CARNOT. *Annales des Mines*, 1892, series 9, vol. i., pages 303-308.

The author states that on comparing the results of exact analysis with those of the ordinary method of assaying (*i.e.*, by fusion with sodium carbonate, charcoal, and strips of iron), he found that the error in the assay was rarely as little as 8 or 10 per cent., and was sometimes more than 20 and even 30 per cent. of the actual proportion of metal present in the ore. Considering the dry method objectionable on the score of the exceeding volatility of antimony, he bethought him of an entirely different process; this consists essentially in dissolving out the antimony from the finely-powdered ore by means of warm, concentrated, hydrochloric acid, precipitating the solution on a strip of tin, then washing, drying, and weighing the metallic precipitate. The foregoing process is immediately applicable to sulphides, as to oxides; the author converts the latter into the more easily treated sulphides, by heating the powdered ore in an atmosphere of dry, sulphuretted hydrogen. The presence of iron and zinc (the latter very rare in practice) in antimony ores does not affect the assay; almost the same may be said of arsenic. But as to lead, a metal which occurs in some varieties of antimony ore, the difficulty of its precipitation in the metallic state, together with the antimony, from the hydrochloric-acid solution, is met by the author in the following manner:—He heats the metallic precipitate to between 122 and 140 degs. Fahr. in a solution of yellow sodium sulphide (obtained by boiling ordinary sodium sulphide with flowers of sulphur). The antimony dissolves rapidly, and there remains a residue of lead sulphide, which is thereafter washed, dried, and weighed. In practice, the weight of the metallic lead is about $\frac{1}{8}$ ths that of the sulphide.

O. S. E.

FUVEAU LIGNITE COAL-FIELD, FRANCE.

Mémoire sur le Bassin de Fuveau. By — OPPERMAN. *Bulletin de la Société de l'Industrie Minérale*, 1892, series 3, vol. vi., pages 833-876, and plates XVIII.-XXVII., inclusive.

The beds in this basin—situated in the Department of Bouches-du-Rhône—are contained in grey, marly limestone of Upper Cretaceous age. There are three beds worked, all included in strata to which the name of “Fuvélian” has been given—the grande mine, at the base of these strata; the quatre pans, some 164 feet higher; and the gros rocher, 33 feet above this. There are several other beds in the Fuvélian strata which are not worked, and also some unworkable beds in other series above and below.

The distances between the beds vary greatly in different places. Their thickness also varies considerably, that of the grande mine ranging from $3\frac{1}{2}$ to $11\frac{1}{2}$ feet,

of which $2\frac{1}{2}$ to 10 feet is coal; the quatre pans bed varies in thickness from 4 to $4\frac{1}{2}$ feet, of which $1\frac{1}{2}$ to $3\frac{1}{2}$ feet is coal; and that of gros rocher from $1\frac{1}{2}$ to $3\frac{1}{2}$ feet, 8 inches to $2\frac{1}{2}$ feet being coal.

The total production of the basin in 1891 was 434,276 tons, practically all of which came from four mines in the hands of three companies.

Valdonne Colliery.—This is divided into three distinct portions by two great faults. Up to 1891, only the northern of these divisions was worked, and this is now nearly exhausted, having almost reached the western limit of the lignite basin, where it is cut off by the underlying Jurassic rocks. In this division the strike of the beds is north to south, and they dip west 1 in 8 in the upper, and somewhat less in the lower levels.

In view of the approaching exhaustion of this portion, a shaft has been sunk to a depth of 1,140 feet in the southern, or middle division, and this will in future be the main drainage-and-winding shaft for the whole mine. The remaining portion is almost entirely unworked.

Gréasque-Fuveau Colliery.—This is bounded on the south by the former. The continuity of the beds is interrupted only by two main faults, with a throw of 60 and 66 feet respectively, both being near the southern boundary. The portion of the concession south of the most northerly of these faults is alone now worked. Here the beds strike north, with an inclination of 1 in 6 to the west. The ground is full of minor faults, which are fewer in the district now abandoned to the north, where, however, they often become "moulières."

Trets Colliery.—This working is situated at the eastern extremity of the basin. Here the beds thin off, and the grande mine alone is workable. Its strike is north-west, with an inclination of 1 in 6 to the north-east. There are few faults, but the "moulières" are frequent.

Gardanne Colliery.—The same three beds are worked here as at Gréasque and Valdonne, with one other, known as the mauvaise mine. A great fault cuts off the beds to the north-east and west, but elsewhere, they are very regular, running north-west, and dipping 30 degs. to the south.

Throughout the basin exceptional difficulties have been encountered in the great quantity of water, which has necessitated heavy expenditure for adit-levels, dams, and pumping machinery. Figures are given of the quantities of water raised, cost of extraction, etc., of the Bouches-du-Rhône Company, from which it appears that 9,900,000,000 cubic metres of water were raised in 1886, at a cost amounting to 3s. 2d. on each ton of coal raised. From this cause considerable areas of coal have had to be abandoned, pending the construction of a long adit at sea-level.

Such faults as are not accompanied by throws, but which let out great quantities of water, are called by the miners "partens." These generally impoverish the coal on either side of the fissure, the sterile areas being termed "moulières." With reference to these, the region may be sub-divided as follows:—

1. The portions south of the Jean-Louis fault, with numerous fissures, rarely open, and often accompanied by throws.
2. The portion north of the fault, where throws are comparatively few, but with numerous "partens," with or without "moulières."

The "partens" tend to lessen in depth, and finish as mere cracks—the "moulières" also lessening proportionally. In the latter, at the point where the bed is cut by the fissure, the lignite is entirely replaced by a yellowish or blackish mud, diminishing with the distance from the fissure. The bed itself thins towards the "parten," the roof first becoming fissured, and finally is found completely fallen in.

The quantity of water underground is found to vary immediately with the amount of rainfall, and in times of drought the flow almost ceases. This does not apply to the Gréasque workings, which seem to be in communication with an extensive water-bearing stratum.

The author then discusses the geological character of the strata in respect of its bearing on the formation of the "moulières;" and finally describes the elaborate system of masonry-dams adopted in order to protect the workings from sudden flooding, etc.

G. E. C.

THE DEEP ADIT-LEVEL IN THE FUYEAU LIGNITE COAL-FIELD, FRANCE.

Note sur le Tunnel à la Mer de quinze kilomètres. By — DOMAGE. Bulletin de la Société de l'Industrie Minérale, 1892, series 3, vol. vi., pages 899-919, and plates XVIII., XXV.-XXVII.

This is a description of the great adit, $9\frac{1}{4}$ miles long, now being driven at sea-level to cope with the water difficulties in the Fuyeau district. Particulars are given of the five principal adits hitherto driven, ranging in length from 820 to 3,565 yards. The history is related of the proposals for a sea-level adit made from time to time from 1859 downwards, culminating in 1879 in the present scheme, which was officially approved in 1889.

The rate of progress was, in 1891, 14·16 feet, and in 1892, 20·27 feet per 24 hours. The high speed is attributed partly to the use of the Berthet hand-perforator, and partly to the system on which the miners are paid, a premium being given for any progress beyond a certain rate per day. At first all shots in the face were fired simultaneously; subsequently, however, it was found advantageous to fire the middle holes first.

The *débris* is removed by means of an endless steel rope, 10 millimetres (0·39 inch) in diameter, carrying 150 tons per day. The ventilation is performed by a Ser ventilator, 23·6 inches in diameter, the waste air passing into the water-channel. This apparatus is calculated to serve for two-fifths of the distance, but the leakage which takes place makes it doubtful if it will serve for the whole. For this reason a ventilating shaft is to be sunk at a point about four miles from the entrance, and possibly another will be required farther in.

An Appendix is added giving details of method of firing, cost, etc., the latter being as follows for the advance heading (6 by 8·2 feet):—

	£	s.	d.	
Labour	1	1	3	
Explosives	1	1	2½	
Coal, steel, and smith	0	1	2½	
Total	£2	3	8	G. E. C.

THE VALDONNE COLLIERIES (FUYEAU BASIN).

Note sur les Mines de Valdonne (Bouches-du-Rhône). By L. VALLA. Bulletin de la Société de l'Industrie Minérale, 1892, series 3, vol. vi., pages 877-897, and plates XXIII.-XXVII.

These mines comprise two concessions, known as Peypin and St. Savournin (north and south) with an area of 650 and 750 hectares (1,600 and 1,850 acres) respectively. They are situated at the south-western extremity of the Fuyeau basin.

For details of the general constitution of the district the author refers to the paper by M. Oppermann in the same journal.* As there stated, the workings are divided into three separate zones by three main faults. The beds run north to south, dipping 10 to 20 degs. in the northern and 20 to 60 degs. in the southern part. There are seven beds, only the three following of which are worked :—

		Total Thickness.		Useful Thickness.	
		Ft.	In.	Ft.	In.
Grande mine	... ..	9	10	8	6
Quatre pans	... ..	5	3	3	11
Gros rocher	... ..	3	9	2	5

Immediately beneath the grande mine there is a bed of inferior coal 5 feet thick ; which, however, is rarely worked.

The lignite is brilliant black, with a conchoidal fracture ; it burns with a long flame and considerable smoke. Analysis shows :—

Moisture	... ..	6.00
Ash	... ..	4.40
Total carbon	... ..	60.65
Oxygen and nitrogen	... ..	25.87
Hydrogen	... ..	3.68

The calorific power is from 5,000 to 5,500 calories ; and the evaporating power 5 lbs. of water per 1lb. fuel.

The greater part of the extraction has hitherto been from the northern portion of the property, where all the hauling-machinery, etc., was situated. Recently, however, it has been transferred to the Armand shaft in the southern portion, where 600 to 700 tons are now raised from a depth of 1,140 feet per day of 9 hours. Owing to this change the production per man has risen from 10 to 16 cwt.

The beds are worked by galleries at an interval of about 660 feet on the dip. Of the grande mine about one-eighth has hitherto been lost in the pillars which were left behind. It is now thought possible to remove all the coal, stone pillars being built up in suitable spots, and walls built along the main roads. In working the quatre pans and gros rocher beds the deads are practically sufficient to fill up the goaves.

Powder is used for blasting both in coal and rock, the holes being bored by a hand-borer. The following comparative figures as to cost of boring galleries 2.50 by 2 metres (8 by 6½ feet) in the country-rock (limestone) are given :—

		Distance driven per 8 Hours.	Cost per Metre.
		Feet.	£ s. d.
Powder	... ..	1.31	2 2 0
Blasting-gelatine	... ..	4.26	about the same.

The Armand shaft is divided into two compartments, for winding and pumping respectively. The winding is performed by two-decked steel cages, weighing 2 tons 7 cwts., guided on steel rails of 40 lbs. per yard. For winding, flat aloes-ropes are used, weighing about 25 lbs. per yard, working at one-tenth of the breaking strain. For raising the men, round steel-ropes are employed, weighing 3½ lbs. per yard, working up to one-twentieth of the breaking strain.

The mines have always been subject, from time to time, to interruption from partial floodings. This, so far as it was due to water penetrating from the surface, has been minimized by establishing sheet-iron conduits in the stream-beds. The water underground now varies little from summer to winter. By this means, and also by the provision of masonry-dams underground, a great improvement has been effected in guarding against floods.

* *Trans. Fed. Inst.*, vol. v., page 556.

The drainage is effected partly by means of underground Tangye and rotary pumps, supplied with steam from the surface, and partly by Cornish and other engines at the surface. In future all the water will be raised by the underground engines from the Armand shaft, the present pumping-plant being reserved for emergencies only. This will give a total power of 2,861 gallons per minute, which should remove any danger from flooding in future.

The total cost of the works in connexion with the new Armand shaft was about £30,000, and it is expected to raise 160,000 tons of coal per annum. G. E. C.

PEAT IN TRANSYLVANIA.

Die Torflager der Siebenbürgischen Landestheile. By GEORG PRIMICS. *Mittheilungen aus dem Jahrbuche der Kön. Ungarischen Geologischen Anstalt*, 1892, vol. x., pages 3-24.

The following peat districts are described:—

(1) Magyar-Valko, province of Kolozs.—This district is estimated to yield 171,990 cubic yards of peat. The quality is very good; its lightness when dried would render it suitable for use in many industries. The hindrances to its profitable working are the great distance from railways, etc.

(2) Ponor, province of Alsó-Fehér.—This district is estimated to yield 390,000 cubic yards of peat. The working of this peat at present is not practicable, as it cannot be reached with waggons. It might, however, without very great difficulty, be sent to the neighbouring towns of Offenbanya and Felső-Szolcsva. The above two peats belong to the class of high moor-peats.

(3) Marótlaka, province of Kolozs, is estimated to contain 234,000 cubic yards of peat of good quality, and tolerably heavy when dried. It is a matured peat, water appears only in the deep parts of the cuttings, and would be no hindrance under a proper system of working. There are no reasonable hindrances to the working of this peat, and carriage will be easily effected, as a railway runs within $1\frac{1}{2}$ miles, and a high road within $\frac{1}{2}$ mile.

(4) Szent-Agotha and Apátfalva, province of Nagy-Kürüllő.—This deposit is estimated to contain 1,300,000 cubic yards of a completely formed and dry peat. The quality is very good. It is situated near good roads of transport for local consumption. There is at present no railway near, but the projected local railway will run near the deposit.

(5) Szombatfalva, province of Udvarhely.—There are numerous mineral springs in the neighbourhood of this moss. The estimated yield is 37,440 cubic yards of good turf-peat (*Rasentorf*). The quality improves with depth. There are no difficulties in the way of working of this peat, as the water can be easily run off into the neighbouring burn, and a high road runs from the place to the Székelyudvarhely railway-station.

(6) Peat region of Middle Csik, along the Alt river:—

(a) The deposit between the town of Csik-Szereda and the parish of Zsögöd, is estimated to yield 1,690,000 cubic yards of pure peat, of good quality, and well matured. In many places there is much ground-water, but not sufficient to prevent the establishment of a large peat factory. The country road runs near, and the projected Székelyföld railway will touch the spot.

(b) The most important peat district in Transylvania is found in the parishes of Csik-Szereda, Taplocza, Csicsó, and Mádéfalva. The estimated yield is 15,600,000 cubic yards of peat. The quality is very good, and peat production could be carried on on a large scale. The projected Székelyföld railway will run near this peat area along nearly its whole extent.

(7) Szerdahely, province of Szeged.—Three unimportant peat mosses, of which the total estimated yield is 1,909 cubic yards. Of the first, the peat is described as unfit for burning, and of the others as of middling quality. G. W. B.

ITALIAN FOSSIL FUELS.

Notizie sui combustibili fossili italiani. By P. Toso. *Appendix to the Rivista mineraria*, 1890, Rome, 1891.

Peat is extensively distributed as follows:—

(1) *Mountain Peat*.—Occurs in the Alps and Appenines, but hitherto has not been found of value.

(2) *Moraine Peat*.—Is found at Varese, Solferino, etc. These are the most important deposits, affording the greater part of the Italian peat produced. The author considers that they would keep up the supply for one hundred years.

(3) *Peat*.—Formed by damming back of water-courses (*Torbiere di sbarramento*). The beds are found over large areas in Vicentino, Velino, near Rieti, etc. The peat is sometimes homogeneous and sometimes earthy. It is only worked at Arcugnano and Santa Croce.

(4) *Estuarine Peat*.—Occurs at the mouths of many of the rivers falling into the Adriatic and Mediterranean seas. It is the most abundant in Italy, but also the most impure and least remunerative to work. It is, however, worked at Codigoras for domestic use, for locomotives, etc.

It is estimated that the amount of peat produced in Italy is about 43,070 tons per annum. The necessity of drying it, and its light weight, are in the way of its increased production.

Woody Lignites.—Beds, over 6½ feet thick, are found at San Giovanni Valdarno, Morgnano, Santa Croce, Sant' Angelo, Branca, Aspra and Roccantica in Sabina, Casina and Castellina in Chianti, and Lefte, near Bergamo. Various deposits of less thickness are also described. The produce is about 331,000 tons per annum.

Pitchy Lignite (ligniti picee).—This fuel occurs in Tertiary rocks, older than the Pliocene. The following localities are mentioned:—Vicentino, Cadibona, Monterufoli, and Murlo. The mine of Montemassi is described in detail, it is estimated to contain 10,275,000 cubic feet of lignite still available. The principal stratum is about 25½ feet thick. It is hoped to raise the annual production of this mine up to 50,000 tons. The quality of the lignite is good, and its calorific power is equal to 0.7 of that of Cardiff anthracite.

The total quantity of pitchy lignite is estimated at 8,570,000 tons, with an annual production of 33,160 tons.

Coal.—Coal itself is scarce in Italy, yet it does occur in the Carboniferous strata of that country. Its rarity is due to the earth-movements and consequent metamorphism which have taken place. Carboniferous strata with coal occur at the following places:—In the Val d'Aosta in the district of Cuneo, on the southern slope of the Maritime Alps, in the valleys of Tanoro, and of Bormida. Other Carboniferous strata containing no coal are also mentioned.

La Thuila in the Val d'Aosta has five or six seams under 1 foot 8 inches each. They are inclined at angles of 40 degs., and therefore difficult to work. The coal contains 25 per cent. of ash, and its heating power is only 5,000 calories.

There are mines at Monfies, Acceglio, Calizzano, and Corongiu Cludinico (Triassic).

Various applications of the Italian lignites for gas-making, for engines, domestic use, and for coke-making, are described. G. W. B.

THE BOLEO COPPER-MINES, MEXICO.

Note sur les mines de cuivre du Boléo (Basse-Californie). By EDOUARD SALADIN. Bulletin de la Société de l'Industrie Minérale, 1892, series 3, vol. vi., pages 5-46 and 283-9, and plates.

The Boleo mines are situated on the western side of the gulf of California, about opposite to the port of Guaymas, which is the terminus of the Sonora railroad. They were discovered accidentally in 1868, by a farmer, who found rounded grains of green carbonate of copper in the sands of the Santa Rosalia rivulet. The first shipment of ore to Europe took place in 1872. The various local companies formed to work the deposits were, in 1885, united under the French Boleo Company, which erected water-jacket furnaces; the production in 1891 reaching 4,176 tons of copper from 76,000 of ore extracted.

The climate is stated to be healthy. The labour employed consists of Mexicans and Yaqui Indians, the latter work well, and are paid at from 1 to 1.75 dollars (Mexican) per day. The whites employed receive 15 to 20 francs per day.

The district is composed of stratified trachytic tuffs, slightly inclined north-east towards the sea, and resting to the south-west on a trachytic upheaval parallel to the coast. The central crest of the peninsula consists of old gneisses and mica-schists, raised probably by granite; but the interior, owing to the entire absence of drinking water, is little known.

The geological formation is divided into four series:—

- (1) The upper beds, consisting of clays, gypsum, tuffs, and fossiliferous sandstone of Upper Miocene or Lower Pliocene age.
- (2) The mineralized beds, consisting of four cupreous beds of varying thickness, interstratified between beds of conglomerate and tuff. Both these conglomerates and the cupreous beds appear to vary as to their contents with the distance from the source whence the detritic materials, of which they are composed, were derived.
- (3) Lower beds. These mineralized beds rest unconformably upon a bed of brown fossiliferous dolomite of indeterminate age. Beneath this is—
- (4) Trachyte, already referred to.

The cupreous beds are similar in general character, and can often only be distinguished stratigraphically. The contents are more or less brecciated, especially in the vicinity of the trachytic outliers, which sometimes interrupt the upper strata. They contain irregular zones of enrichment; and the contents, from a mineralogical point of view, are very varied. The fundamental gangue is a hydro-silicate of alumina, often very siliceous, and the predominant copper minerals are green and blue carbonates, black oxide, ferruginous crednerite, and various sulphides.

Near the outcrops the ores are entirely converted into carbonates, or into atacamite; while the iron pyrites is completely oxidized. Farther down, the carbonates are rare; the proportions of black oxide, and still more of sulphide, increase. The author questions whether the original deposit was in the form of sulphide, preferring to consider it to have been a mixture of this and oxide.

The first bed has been much eroded, and is of little industrial importance. The second is characterized by the comparative rarity of ferruginous matter and the abundance of silica in the gangue. The mineral is often of a granular nature, and is generally concentrated towards the floor. The thickness varies up to 3 feet.

The third bed varies in thickness from 0.20 to 2 or 3 metres (8 inches to 6 or 10 feet), and has been most extensively worked. It is not only richer, but the nature of the gangue enables a better smelting mixture to be made. Most of the ore is so finely disseminated in the gangue as to render dressing impossible.

The following analyses give an idea of the chemical composition :—

Moisture at 110°.	SiO ₂ .	FeO.	Al ₂ O ₃ .	MnO.	CaO.	MgO.	OnO.	Sulphur Total.	Loss by Heat.	Cu.
25.11	39.18	7.34	10.16	3.30	3.21	3.74	12.39	2.16	16.80	9.80
18.35	31.77	14.25	2.16	15.44	3.88	2.31	12.05	0.44	16.38	9.63
25.00	22.85	12.50	2.04	11.08	3.21	3.21	9.86	0.62	11.05	7.89
20.00	22.80	10.08	4.38	7.20	6.16	4.43	7.50	3.03	14.56	6.82

The moisture on extraction reaches 25 to 30 per cent., which on exposure to the sun is reduced to 15 per cent. The ore contains a little salt, which explains the corrosive action in the furnaces as arising from the giving off of a little hydrochloric acid.

The author considers the beds to be the product of re-arrangement of pre-existing beds of more equal richness, and thinks that the future of the poorer parts, now unworked, rests with the adoption of a wet chemical process of treatment.

There is nothing special to notice in the methods of working. Most of the selection is done in the mine, all the workings of which are above the water-level. In order to ensure regular supply, the ore as extracted is stored in ore-bins of large capacity, before being carried to the works ; which are connected with the mines by a 3-foot tramway of 30 kilometres (18½ miles) in length.

The ore is smelted entirely in water-jacket furnaces of ordinary type. It is stored in different bins, according to composition, so facilitating the attainment of a suitable smelting mixture. The smelter consists of 4 large rectangular and 2 smaller circular furnaces. Sea-water is used to circulate in the jacket, with fairly good results. The rectangular furnaces are of 80 to 100 tons, and the circular furnaces of 40 to 50 tons per day capacity. About 150 kilogrammes (330 lbs.) of good coke are used per ton of smelting mixture, the large furnaces being slightly more economical in this respect. The chief economy they afford is in labour, supervision, and cost of repairs.

The fines are compressed by the aid of a little water into balls by a machine on the Beer system ; they do not need drying before smelting. The blast is furnished by Baker and Root blowers. Notwithstanding the corrosive action of the sea-water used for the jacket, the furnaces usually give campaigns of over three months' duration.

No fluxes are required. The sulphur present is all taken up by the copper, forming matte, the rest being given as black copper. The slags contain on an average 1 per cent. copper.

The following analyses are given :—

MATTES.

Copper	...	...	...	...	96.250	...	73.08
Iron	...	...	...	...	0.830	...	4.24
Sulphur	...	...	...	...	0.767	...	19.61
Manganese	...	...	...	...	traces	...	1.05
Arsenic and antimony	...	...	...	...	nil.	...	nil.
Loss, etc.	...	...	...	...	2.153	...	2.02
					<u>100.000</u>		<u>100.00</u>

SLAG.							
Silica	...	...	...	...	...	...	41.60
Alumina	...	...	...	...	...	...	10.26
Oxide of iron	...	...	...	...	...	...	15.57
Oxide of manganese	...	...	...	...	...	...	19.76
Lime	...	...	...	...	...	...	5.50
Magnesia	...	...	...	...	...	...	6.12
Oxide of copper	...	...	...	...	...	...	1.12
							99.93

At present English coke only is used, but it is not improbable that it may be replaced by anthracite, at a considerable saving.

The total number of workers employed is about 1,200.

G. E. C.

THE COPPER REGION OF MICHIGAN.

BY F. B. PHELPS. *Engineering Magazine (New York)*, vol. ix., pages 47-63.

The native copper deposits of the Keweenaw promontory occur as amygdaloid and conglomerate-beds interbedded with trap, resting on sandstone. The conglomerate-beds, ranging in width from 4 to 30 feet but fairly uniform, dip west, at an angle of from 32 to 52 degs. towards Lake Superior. The similar beds in the Isle Royale, an island in the lake 40 miles from the American shore, dip east; and it is surmised that they are the opposite outcrops of a continuous basin.

Ancient pits and implements prove mining here to be of great antiquity. The first modern workings on a large scale were in the northern region, from 1840 to 1850; but the exhaustion of the deposits, and the fall in prices, led to its almost complete abandonment. The great mining region is now in Houghton county, to the south, where the well-known Atlantic and Osceola (amygdaloid), Calumet and Hecla, and Tamarack (conglomerate) mines are situated. The mode of working is by inclined shafts on the foot-wall, with levels at regular intervals of 100 feet, the conditions for symmetrical mining being almost perfect.

At the Calumet and Hecla mines, the lode varies in width from 8 to 30 feet, with an average of 12 feet. The whole of the deposit is mined out, and the roof supported by very heavy timbering. The greatest depth reached at present is 3,850 feet on the incline, or about 2,350 feet vertical. The ore is stamped and dressed by hydraulic separators, the slimes being treated by round tables. The Tamarack Company works the ground to the west beyond the Calumet boundary, by means of deep vertical shafts. The first of these sunk cut the lode at a depth of 2,270 feet vertical.

The working of the amygdaloid beds is similar; the ore, however, is much softer.

G. E. C.

THE UNDERGROUND FIRE AT THE LAKE SUPERIOR MINE, ISHPEMING, MICHIGAN.

BY J. PARKE CHANNING. *The Engineering and Mining Journal (New York)*, 1892, vol. liii., page 106.

The author has witnessed nine mine fires in the Lake Superior region, during the last eight years; five of which fires he had the opportunity of closely inspecting.

The conclusions arrived at by his experience are: that the best way to extinguish a mine fire is to cut off the supply of oxygen as quickly as possible, and to be very

careful not to open up too soon after the fire is supposed to be out. Steam is excellent, when it can be applied in the immediate vicinity of the combustion. He has not much faith in the use of artificial carbonic acid. While it is supposed to be heavier than air and to settle down to the bottom of the mine, it is, as generated from the tanks, very hot from the heat engendered by the chemical reaction producing it, and, consequently, it hangs around the collar of the shaft. A fierce fire will soon use up all the oxygen in a sealed-mine and then carbonic acid will be present in far larger quantities than can be generated by chemicals on the surface.

J. W.

OUTBURSTS OF CARBONIC ACID GAS AT THE ROCHEBELLE COLLIERIES, FRANCE.

Les dégagements d'acide carbonique aux mines de Rochebelle. By C. LANGE. Bulletin de la Société de l'Industrie Minérale, 1892, series 3, vol. vi., pages 1,141-1,180, and plates XXXIII-XXXV.

The mines comprise two distinct regions, in which carbonic acid and fire-damp are respectively given off. The presence of the carbonic acid was observed from the first, but it did not give rise to any serious danger up to 1880, and mechanical ventilation was not thought necessary.

Besides the smell and sour taste, a sensation of warmth is felt in the portion of the body immersed in the gas; so that its presence is easily detected. Like fire-damp, it is enclosed in the pores of the coal, but with great irregularity; and almost certainly it did not originate *in situ*.

The mines occupy the southern portion of the Gardon basin, the beds being included in the lower system of the Gard coal-field. The concession is included between the great fault of the Cévennes to the east and the ancient schists of Mont Cabane to the west. Near the former the beds are much bent and fissured. To the north, in the valley of the Gardon, they are covered by Secondary measures (Trias and Lias); at the base of the Lias important deposits of iron pyrites and oxide of iron are worked.

The workings are classed into three groups, those of Rochebelle, Cendras, and Fontanes, at all of which more or less carbonic acid is present. At Fontanes a schistose formation predominates, which is less fissured than the compact sandstones at Rochebelle. Probably for this reason, the carbonic acid at the latter is contained in the fissures, while at Fontanes it seems to be enclosed in the coal. It appears to be diminishing in quantity at Rochebelle, and to be replaced by fire-damp—which, however, was not observed until 1886. The author considers the carbonic acid to be of volcanic origin, and to have been brought in by the Soulier fissures, which also conveyed the mineralized solutions which gave rise to the pyrites deposits.

He next describes in detail the various outbursts of carbonic acid. These at Fontanes were so sudden as to be practically explosions. They gave out enormous quantities of gas, and threw down a great deal of coal—amounting at times to hundreds of tons. In several cases the loss of life was serious.

At Rochebelle the outbursts were produced with less force; and instead of coming from the solid coal, they proceeded from open fissures, full of water and carbonic acid. The walls of these fissures are found to be covered with quartz-crystals with liquid enclosures, blende, galena, and pyrites.

In every case the outbursts have been preceded by one or more of the following symptoms:—Heaviness of the atmosphere; frequent dull explosions; pressure in the boreholes; detachment of plates of coal, with decrepitation, and changes in the physical state of the coal.

The force of the outbursts appears to increase with the depth.

Experience has demonstrated that the most useful precautions to be observed when the presence of the gas is suspected are:—(1) Arrangements for supplementing ventilation; and (2) entire suppression of the use of the pick, and working solely by means of shot-firing: the workmen to retire behind solid barriers at the moment of firing.

It was found that boreholes were quite useless to drain the gas from the coal.

G. E. C.

ORIGIN AND DISTRIBUTION OF GOLD AND PLATINUM, NORTH COAST BEACHES, NEW SOUTH WALES.

By J. W. ARCHIBALD. Australian Mining Standard, vol. ix., pages 193 and 220.

The gold in these deposits occurs in seams of black sand; it is always fine, and associated with the rare metals of the platinum group. The black sand is found only at the high-water line, or in the sand terrace forming the foreshore; the former being in many cases naturally concentrated from the latter. It usually presents no difficulty in amalgamation; south of the Evans river, however, part of the free gold, though bright, can only be saved in the blanketings.

In the vicinity rock-formations are met with, carrying the various metals found in the sands. A sample of the blanketings from the latter contained:—Gold 27 ounces, platinum 17 ounces, and osmiridium 140 ounces per ton. No free gold was visible, this having been extracted by amalgamation. Rock-samples from near by gave:—Gold 10 dwts., platinum 9 dwts., and osmiridium 21 dwts. per ton. When concentrated, the residue was heavy brown sand, neither gold nor platinum being visible. As an example of these formations the "Iron Gates" of the Evans river is cited. This is a gossan deposit, about 1 chain wide, lying parallel with the coast, and imbedded in the coal-formation, the sedimentary rocks appearing unaltered at the contact. This deposit carries 1 to 2 ounces per ton of the combined rare metals.

Many other such outcrops occur in the neighbourhood, and the natural inference is that the beach-sands are derived from them, their subsequent distribution being effected by sea-action.

G. E. C.

THE MOUNT MORGAN MINE, QUEENSLAND.

By T. A. RICKARD. Transactions of the American Institute of Mining Engineers, 1891, vol. xx., pages 133-154.

Mount Morgan mine is situated 26 miles south west from Rockhampton, in central Queensland. Up to November 30th, 1890, £2,358,333 had been paid in dividends, the total gold obtained being 756,042 ounces, worth £3,121,741. The property consists of the original selection of 640 acres taken up for grazing purposes in 1873 by Mr. Donald Gordon. Becoming acquainted with Messrs. Morgan Brothers, who also held land in the district, he showed them one day a piece of gold-bearing quartz which he had picked up in Mundic creek. For a consideration, Mr. Gordon agreed to indicate to them the locality of the find. On the hill, overlooking the creek, he showed them the siliceous ironstone, some of which can still be seen cropping out on the north-eastern slope. The stone carried visible gold. They found, by sending samples to Sydney, that it was even richer than they had imagined. So they purchased Mr. Gordon's holding at £1 per acre. The Messrs. Morgans, later on, sold first a part, then the whole of their interest in the mine. In 1886 a company

was formed with a capital of 1,000,000 shares of £1 each. These shares rose toward the end of 1888 to £17 5s., giving the mine a market value of £17,250,000.

The author gives a description of the workings.

Examination of the many varieties of ore shows that while there may be a great difference in outward appearance due to coatings of multi-coloured oxides, the ore is always substantially quartzose.

The origin of the Mount Morgan ore-deposit has been the theme of much controversy. The three chief theories (each of which the author discusses at length) are:—1st, That the deposit is that of a geyser; 2nd, that it is an auriferous zone traversed by a series of quartz-veins of auriferous mundic; and 3rd, that it is the decomposed cap of a large pyrites lode.

Mr. Rickard considers that a period of dynamic disturbances is indicated by the intrusions of dolerite, which, by extreme metamorphism, might have changed a dolomite into the serpentine we now see, would have indurated the shales so that they are scarcely to be distinguished from the crystalline rocks; and would also, accompanied by chemical alteration, change a ferruginous red sandstone into a bluish-grey, highly pyritiferous quartzite. Approaching the surface, the same energy would be expended in the fracturing of the quartzite and the graywacke; the intrusive dolerite would rise through the fissures in the shattered rocks, forming dykes, which, meeting a silico-felspathic granular rock (the graywacke), would give it a semi-crystalline character. The sandstone would similarly be vitrified. Later movements would result in the further intersection of this part of the district by the numerous dykes, the decomposed remains of which are now to be seen ramifying through the deposit. Those gradual chemical interchanges would take place which resulted in the alteration of the shattered country-rock, and its becoming a portion of the gangue enclosing the auriferous material, which was then, or at a later time, deposited. In process of time, subaërial denudation removed the sandstone, which now is only to be seen on the further summits of the neighbouring hills. Atmospheric agency continued to carve away the less siliceous and less porous portions of the country surrounding the deposit, until Mount Morgan, owing to the pervious, quartzose nature of its crest, remained as a low hill in an undulating country.

Since writing his paper, the author has visited and examined the equally famous Broken Hill silver deposit, and the latter confirms a statement he makes that the material of the Mount Morgan ore could be duplicated elsewhere. At Mount Morgan all the conditions generally considered favourable to ore deposition were present in a marked degree. A mass of country-rock, whether graywacke or sandstone, consisting of granules of quartz, held together by a felspathic cement, becomes fractured by the intrusion of a series of dykes, which form a ready passage for the flow of mineral solutions. Such a rock would readily lend itself to alteration, and would be well fitted to receive a mineral deposit. Later dynamic action produced a further metamorphism of the surrounding rocks, followed or accompanied by the intersection of the already shattered rocks by another series of dykes, which reopened a passage for the underground waters. In this case it is not necessary to go far for the source of the gold. The large mass of decomposed pyritic quartzite, though the pyrites contains but a trace of the precious metal, is more than sufficient to account for the wealth that has been uncovered.

Finally, says Mr. Rickard, there is no need to offer any particular reason for the unusual richness of the deposit, beyond the eminently favourable condition of the original rock, the numerous channels offered to percolating waters, and the close proximity both of the sources of the gold and the usual precipitants. J. W.

INFUSORIAL EARTH.

La Gloria Infusorit. By G. PETIT. *Génie Civil*, 1892, vol. xxii., page 77.

The deposits of infusorial earth, to which the name of *Gloria infusorit* has been applied, at Celle in Hanover, and Klicken in Anhalt, are of great extent. They occur in basins, often attaining a thickness of 66 feet (20 metres), from 3 to 15 feet (1 to 5 metres) below the sandy surface. They present three distinct qualities, white at the bottom, then grey, and green at the top; this latter resulting from the vegetable products which have worked in from the surface, and which often form 40 per cent. of the whole.

The main use at present is in the manufacture of dynamite; but it is also suited for all purposes where a good non-conductor of heat is required. G. E. C.

JADE IN UPPER BURMA.

Note on the occurrence of Jadeite in Upper Burma. By DR. FRITZ NOETLING (with a map). *Records of the Geological Survey of India*, 1893, vol. xxi., pages 26-31.

The chief interest of this paper is the description of the manner of occurrence of jade. It is found forming the central portion of a dark eruptive rock closely resembling serpentine, and separated from the outer rock by a band of soft clayey serpentine. The rocks through which the serpentine has been erupted are probably of Miocene age. G. W. B.

IMPROVEMENTS IN COPPER SMELTING.

By E. D. PETERS, JUN. *Australian Mining Standard*, vol. ix., pages 276 and 288.

Pyritic smelting, *i.e.*, smelting pyrites by the heat generated by the combustion of the contained sulphur, is stated to be successfully performed in the United States, at Leadville, Kokono, and Boulder, by heating the air-blast. This concentrates the temperature in the lower part of the furnace, so preventing the ore in the upper part from becoming soft and clogging. An ordinary water-jacket blast-furnace is used, and the smelting commenced as usual. After it is working well the proportion of coke is lessened, until with pure pyritic ores it may even be dispensed with entirely. At Boulder, where the sulphur in the charge averages 20 per cent., about 2½ per cent. of coke is added, as against 15 per cent. formerly required. A large proportion of fines is of course a hindrance, and over 40 per cent. would render the method inapplicable; as also would over 5 per cent. of lead or zinc sulphides.

The rest of the paper contains a description of the Manhès process of Bessemerizing copper mattes. G. E. C.

MANGANESE IN THE UNITED STATES.

Manganese. By R. A. F. PENROSE, JUN. *The Engineering and Mining Journal* (New York) 1892, vol. liii., pages 38-39.

Production.—In 1891, the production of manganese ore proper, independently of manganiferous iron ores, manganiferous silver ores, and manganiferous zinc ores, has been probably less than 20,000 tons. The production for 1889, was 23,927 tons, whilst the largest annual output in the United States was in 1887, when 34,524 tons were mined.

Most of the manganese ore of the United States is produced in the States of Virginia, Georgia, and Arkansas, mentioned in the order of the quantity of ore produced; while smaller amounts are derived from Leadville, Colorado; San Joaquin County, California, and the Lake Superior region of Michigan. The old manganese workings at Brandon, Chittenden and South Wallingford, Vermont, were idle in 1891.

Methods of Mining, etc.—The largest manganese deposits in the United States—those of Virginia, Georgia, and Arkansas—occur as irregular nodules, layers, and pockets in clay. They are usually worked by shafts and drifts, and the loose character of the ground frequently necessitates expensive timbering. In some cases large open-cuts have been worked successfully. In Colorado and California the deposits occur in solid rock, and the ore is obtained by the ordinary process of mining.

The ore in the clay is usually washed before shipment in an ordinary iron-ore washer, as in Virginia and Arkansas, or in revolving perforated cylinders as in Georgia. The smaller ore is also sometimes cleansed by jigging.

Uses of Manganese.—Over nine-tenths of the manganese production of the United States is consumed in the manufacture of ferro-manganese and spiegeleisen for use in steel-making. The rest, usually the higher grades from Virginia and some from Georgia, is consumed in the manufacture of bromine, in clarifying glass, in making manganese bronze, silver bronze, and other alloys, besides in small quantities for numerous other manufacturing and chemical purposes. J. W.

THE RUSSELL PROCESS AT THE SOMBRERETE MILL.

By E. H. RUSSELL. *The Engineering and Mining Journal (New York)*, 1891, vol. li., page 140.

The Russell process (English patents, 5431, March, 1884, and 6102, April, 1888), has for its object the recovery of silver and gold existing in ores as metallic silver, as sulphides of silver or gold, or as compounds of silver with antimony or arsenic, and which cannot be extracted by leaching with sodium hyposulphite alone. The leaching solution employed in the Russell process consists of an ordinary hyposulphite solution to which has been added a soluble compound, preferably the sulphate of copper. A double salt of cuprous sodium hyposulphite is thus formed in which the copper can be replaced by silver, the eliminated copper taking the place of the silver in the compound decomposed by the solution. The solution is made by adding 1 to 3 per cent. of the copper salt to a 1 to 5 per cent. solution of hyposulphite of soda. The gold and silver are recovered by precipitation as sulphides. According to the newer method, protected in 1888, the copper sulphate is first mixed with the crushed ore, so as to replace by cupric hydrate any of the injurious metallic hydrates which may be present in the charge. When this neutralizing action is complete, the usual sodium hyposulphite solution is added, this reacts with the copper, already present in excess, to form the cuprous sodium hyposulphite.

The series of experiments reported on were instituted with a view to determine the best mill methods for the treatment of Sombrerete ore, and to decide what changes might be necessary in the new plant.

The experiments were confined to ore from the San Francisco mine, an approximate analysis of which was as follows:—

FeS₂, 40 per cent; ZnS, 12 per cent; PbS, 13 per cent. and insoluble residue, 34 per cent.

The blende assayed 80 ounces of silver per ton; the galena 70 ounces, and the pyrites 35 ounces.

The leaching work done in the mill was so thorough that the average apparent mill extraction, in the whole 127 charges (40 tons each) treated, exactly equalled the result of the assay-office leaching test on the samples of these charges, and for the last 10 of the 13 mill runs, exceeded the assay-office results by 1·4 per cent. These experiments at the Sombrerete mill ran over 93 days, 4,935 tons of ore being crushed.

The whole series of experiments was divided into three sections, according to the general method pursued in the roasting, as follows:—

(1) *Furnace Roasting without an Air Blast and without a Preliminary Field-roasting.*—The following results were obtained by this method of working:—

Per Cent. of San Francisco Ore used.	Mesh of Screen for Ore.	Mesh of Screen for Salt.	Per Cent. of Salt.	Per Cent. Extraction by Extra Solution in Assay Office.
100	60	30	17	92·3
100	60	0	0	71·4
76	30	12	12	74·6
90	24	12	14	71·1
100	24	12	12	54·5

(2) *Furnace Roasting with Air Blast in the Furnace, but without a Preliminary Heap-roasting.*—With this method of roasting, and with an ore containing only 17 per cent. of sulphur, crushed through a 24-mesh screen and roasted with 11·5 per cent. of salt added to the raw ore, the actual mill extraction based on raw-ore weights and values was 79·8, or if based on roasted-ore weights and values 95 per cent. All the ore treated under this section was crushed by rolls. The result showed that for roasting, except after fine crushing, the sulphur contents of the ore should be reduced.

(3) *Furnace Roasting after a Preliminary Heap-roasting.*—With the object of reducing the sulphur contents of the ore, heap-roasting was adopted. The piles were built as follows:—Trenches about 1 foot in depth and width were dug about 2 feet apart. Similar trenches were made at right angles across these. All were covered with old grate-bars or flat stones, laid an inch or two apart. The trenches, under the grate-bars, were then filled with kindlings and the ore was piled on top to a height of from 6 to 12 feet. The following features about the heap-roasting were worthy of note:—No silver was lost; the amount of fuel required was about one-half cord of wood per 500 tons of ore; and the piles burned rapidly, a 300 tons heap only requiring four to five days. With such rapid burning, however, the interior of the pile sintered. This was remedied by covering the pile with fine material, to cause slower combustion. All the field-roasting was done at the mine, scarcely any extra handling of the ore being required. The apparent extra expense of heap-roasting was about 15 cents per ton. Really, there was no extra expense as, by heap-roasting, the drying of the ore at the mill, which was otherwise necessary, and which cost 25 to 30 cents per ton, was avoided. During this section of experiments the salt used in roasting averaged 8·7 per cent. of which 1 per cent. was added to the raw ore and the remainder thrown into the shaft and return flue of the furnace on top of the roasted ore.

The average number of pounds of chemicals used per ton in leaching was:—Hyposulphite, 1·8; bluestone (copper sulphate), 6·3; sodium carbonate, 6·3; caustic soda, 4·0; and sulphur, 2·6. The strength of the stock solution was 1·5 per cent. of hyposulphite, and of the extra solution, 0·70 per cent. of bluestone.

The average time of charging vats (50 tons) was 8 hours: of first washing, 12 hours; leaching and second washing, 46 hours; sluicing-out tailings, 1½ hours; or a total of 67½ hours.

The average loss of silver by dust from machinery and furnace, and by volatilization in roasting, during the experiments of this section was 3·6 per cent. of the raw ore weights and values, that of the last run being 1·3 per cent. The actual mill clean-up, based on raw ore weights and values for all the experiments of this section was 86·3 per cent., that of the last run being 90·9 per cent., or, if based on roasted ore weights and values, 93·0 per cent.

Summary.—The changes in mill methods and the results obtained in the treatment of Sombrerete ore, containing about 66 per cent. sulphides, are summarized as follows :—

All drying of the ore at the mill was discarded; the ore crushing was changed from 60-mesh to 6-mesh; the fineness of salt used was changed from 30-mesh to using it uncrushed and undried; the method of using it was changed from adding it to the raw ore to adding it to the roasted ore; the amount of salt used was reduced to 6·5 per cent.; the loss of silver, as dust and by volatilization, was reduced to 1·3 per cent.; the results of leaching in the mill equalled and exceeded the results which could be obtained by assay-office leaching tests on the same roasted ore. The results attained on all heap-roasted ore averaged 86·3 per cent. actual extraction, based on raw-ore weights and values, or 90·9 on the last run, or 93 per cent., based on roasted-ore weights and values; all of which were about such as would be obtained in the same running time and with the same amount of ore in any new mill. The results at the Sombrerete mill compared with those of the Marsac mill (Daly Mining Company) were as follows :—

	Silver. Ounces per Ton.		Gold. Value per Ton.		Per Cent. Silver extracted.		Per Cent. Gold extracted.		Cost of Mining per Ton.		Cost of Milling per Ton.
Sombrerete	40·00	...	\$2·25	...	83·0	...	50·0	...	\$6·79	...	\$6·48
Daly	43·40	...	1·35	...	89·2	...	41·5	...	5·50	...	6·40
											J. W.

THE PRACTICAL CHLORINATION OF GOLD-ORES AND THE PRECIPITATION OF GOLD FROM SOLUTION.

By JOHN E. ROTHWELL. *The Engineering and Mining Journal (New York)*,
1891, vol. li., pages 165-166.

The author gives records from successful working experience on a large scale. The chief objection to a plant of a capacity of 50 tons, or more, per 24 hours, for the Plattner (chlorination) process is its large size and the length of time required for a single operation. The problem to be solved by the engineer, therefore, in handling low-grade ores that will not concentrate, is to find a process that will treat large quantities of ores quickly, cheaply, and with as little interruption as possible. In the reduction works of which this article treats, the ore was crushed dry, in Blake and Gates crushers and in two sets of Krom rolls, roasted in Brückner furnaces of three tons' capacity, and chlorinated in barrels of three and four tons' capacity.

Crushing.—Preliminary experiments must be made to ascertain how coarse the ore may be crushed, so as to yield the best results. The pulp for the best leaching must be in granular condition and carry as small a percentage of dust or slimes as possible. Rolls, properly managed, are especially well adapted for this purpose.

Chlorination.—The barrel is made to serve also as the washing and leaching vessel by placing a supporting diaphragm, for a filtering medium, to form the chord of an arc of the circle of the barrel. This filter (or diaphragm) is made of plates, corrugated as for an ordinary filter-press, and perforated with holes every four, or six inches square. The plates are supported on segments which are bolted to the shell; on the top of the corrugated plates is placed the filtering medium, an open-woven

asbestos cloth. Two methods are described for charging the pulp and chemicals—bleaching powder and sulphuric acid. When the chlorination is completed, the barrel is stopped so that the filter is left in a horizontal position, a hose is attached to one of the outlet pipes and conducts the solution to a reservoir-tank.

The method of leaching is described, the washing being conducted so as to prevent escape of chlorine gas. The solution runs into a covered tank, from which a fan exhausts into the atmosphere, outside of the building. The water used was 100 gallons per ton of ore for chlorination, and 120 gallons more for leaching. By using the washings over again, the volume of solution to be precipitated is kept down to 120 gallons per ton of ore.

The advantages of this method are said to be:—Considerable saving of skilled labour, freedom of the building from chlorine gas, control over leaching of charge, and the small amount and simplicity of machinery for amount of work done. One intelligent man and a helper can look after the charging, leaching, and discharging of three barrels.

Precipitation.—The writer has found hydrogen sulphide gas, generated from paraffin and sulphur, or from iron sulphide and sulphuric acid, to be the cheapest and most satisfactory precipitant. The hydrogen sulphide gas is forced through the solution by a small air-pump, which at the same time forces air through, this agitates the solution and expels the free chlorine gas. Precipitation is thus rapidly effected and the precipitate settles well in a flocculent form. The asbestos filter cloth can be changed in about $1\frac{1}{2}$ hours, and will last for over 100 charges.

The wear and tear of the plates, grating and lining of barrel is said to be very slight indeed.

J. W.

THE CHLORINATION OF GOLD-ORES.

By J. H. BURFEIND. *The Engineering and Mining Journal (New York)*, 1891, vol. li., page 446.

An outline of the Plattner process is given, as worked at Douglas Island, Alaska, by the Alaska Treadwell Gold Mining Company, which works turn out more gold than any other works in the United States.

Firstly, with regard to precipitants, the author finds none equal to ferrous sulphate for general use. Its preparation is simple, requiring no machinery; the material is cheap and always at hand; its cost is less than any of the others offered to replace it; its application is simple and its action entirely satisfactory.

The main objection to the use of hydrogen sulphide is that it precipitates copper, as this metal is rarely absent, and the separation of the sulphides is always difficult.

The works at Douglas Island have been in operation about seven years. The material treated is the sulphides collected by the Frue vanners in the stamp mill. They contain on an average over 40 per cent. of sulphur, mostly in iron pyrites, although of late a good deal of copper pyrites has made its appearance. The gangue is quartzose, with from 2 per cent. to 5 per cent. of calcite.

The first improvement made was to replace the Brückner with the automatic Spence furnace. The latter did not answer at all until changed from a muffle to a reverberatory. Six of them were built at a large expense. The cost of roasting in them was less than half that in the Brückner; but their capacity was small and fuel consumption large. An old-style reverberatory furnace was also added and such satisfactory results were obtained by it that the company decided to use them entirely. The six double Spence furnaces were thrown out, and now the work treat nearly twice the amount of material with only four reverberatory furnaces.

These four furnaces, built after the plan of Mr. H. Stansfield, are 13 feet by 65 feet inside measurement, and handle about 20 tons of material daily at a cost much less than could be done with the Spence furnace.

The roasted ore is removed from the pit under the furnace, spread on the floor to cool somewhat, then wetted sufficiently, sifted into vats, each holding about $4\frac{1}{2}$ tons, and the chlorine gas is put on. Four hours, on an average, are sufficient for the gassing operation; after which the vat is allowed to stand 20 to 30 hours.

The leaching usually takes 12 hours. For convenience, and to avoid breakage of filters, etc., the solution is run into intermediate tanks and thence to the precipitating vats in which is already placed the necessary amount of the precipitant, FeSO_4 . The precipitation is complete by the time the vat is run full. The solution is then stirred briskly for a few moments and left to settle for 18 to 24 hours. The supernatant liquor is then drawn off and allowed to go to a large filter. Tests show that this waste liquor, when down, contains gold still in suspension, equal to 23 to 25 cents per ton of material treated, and this is entirely saved by the filter. A clean-up is made twice a month; as, if only once a month, the amount of gold is too much for one man to handle. The drying and melting of, say, 12,000 dollars (£2,400) can easily be done by one man in one day. The dried gold, from the clean up, is melted into bars with a little borax.

A chlorination-vat holding about $4\frac{1}{2}$ tons of roasted material costs 50 dollars (£10), and lasts fully three years without any repairs. The filter in it costs only the price of a few gunny sacks, will last six months, and needs no attention during that time. The other vats will last a lifetime and not need more than an occasional hoop. There is not a piece of machinery in the works, an advantage that is fully understood by a practical chlorinating man. The real difficulty which is universally met is in the roasting of the material. Most of the ores now treated by chlorination are roasted with salt. Whilst intelligent operators have succeeded in reducing the loss of gold, which occurs by volatilization very largely when salt is used in roasting, it is still very large and occasionally will increase to an alarming extent without any apparent cause. The loss from this source amounts to an enormous annual aggregate, and is often the reason why well-arranged and well-conducted works prove financial failures.

J. W.

LEAD-ORES OF MAZARRÓN, SPAIN.

Criaderos Metalíferos de Mazarrón. By F. B. VILLASANTE. *Revista Minera*, vol. xliii., pages 145, 155, 163, and 169.

The mineral deposits of Mazarrón are of two classes—veins and masses. To the first class belong the lead veins, which form the wealth of the district, the occasional veins containing copper ores being of no importance.

The lead veins contain more or less argentiferous galena, often intimately mixed with blende, and this latter is sometimes very largely in excess. The containing rock is always trachyte, and when this disappears in depth the fissure which has formed the lode continues, but is always barren.

The galena is either laminar, radiated or granular; in the first case being usually richer in lead and in the second in silver. The richness is very variable, in some cases being 65 to 80 per cent. of metallic lead—in others not more than 10 to 12 per cent. The average may be taken at 30 per cent., which by mechanical concentration may be raised to 50 per cent. The ley in silver varies from 1 ounce and 2 ounces per quintal to $3\frac{1}{2}$ ounces, 2 ounces being very common; but in one district there are veins of carbonate very poor in lead, but with 6 ounces of silver as the average

The direction of the more profitable lodes is pretty constantly north and south, within a few degrees. There are lodes running east and west, but these, with few exceptions, are barren. The inclination varies from 45 degs. to vertical, dipping more generally to the east. Changes of inclination are, in many important lodes, very frequent. The width also varies greatly, from 8 inches to 16 feet (0.20 of a metre to 5 metres). Geodes (vughs) are infrequent, and are generally small fissures or irregular cavities full of earthy dolomite.

The mineral constituents of the lodes vary greatly, not only at different depths, but even at the same level. Near the surface the galena almost completely disappears, being replaced by carbonates, phosphates, and arseniates of lead, and there is also a great deal of brown hematite. The superficial decomposition of the trachytes by the metalliferous solutions permeating the fissures has given rise to the formation of alunite, which forms the best evidence of the existence of a lode.

The richness of the veins has been observed to be greatest in their most vertical portions, in accordance with the theory of Moissenet. It has hitherto been considered that the richness in silver diminishes with depth, but two important discoveries which have been recently made do not favour that assumption.

Not all the lodes reach the surface, although the more important do; the remainder may be considered disconnected branches from these. The course is, as a rule, exceedingly irregular, and even when the fissure continues for a long distance, the width and contents are extremely variable.

In the succeeding numbers the author describes the various mines in detail.

In the Fortuna district the two dominant directions of the lodes are north 15 degs. east and north-west. The inclination is always nearly vertical, with a slight tendency to dip north-west. The thickness can hardly be determined, owing to the small depth hitherto attained, but may perhaps be put at about 3 feet. The minerals present and the ley in silver vary greatly, but in the former group the general rule is for the proportion to be 9 to 10 ozs. silver per quintal of lead, in the latter group not more than 4 ozs. The outcrops are very numerous, and generally traces of old workings.

With reference to the iron deposits, in the Santa Justina mine they consist of superficial pockets intercalated in Tertiary limestones. The average percentage is 50 per cent., with a little manganese.

The Vulcano mine is an east-and-west lode dipping north, and for a time yielded 1,000 tons of ore monthly. At a depth of 328 feet (100 metres), however, it disappeared, and its continuation could not be found.

G. E. C.

MICA MINES OF CAROLINA, U.S.A.

Mica and the Mica Mines. By C. HANFORD HENDERSON. *Popular Science Monthly* (New York), vol. xli., pages 652-665.

The mica mines of the western part of North Carolina are described. The country rock is Huronian or Laurentian granite and gneiss, dipping at an angle of 45 degs. or more. Commonly the veins occur in a fine-grained black gneiss known locally as "slate." They usually dip with the bedding, but sometimes cut across it; and vary from under an inch to 10 or 12 feet thick. The contrast between vein-stuff and country is very striking, the felspar in the former giving it a glistening white appearance. The vein-filling consists essentially of mica, quartz and felspar, very coarsely crystalline, the mica having crystallized out first.

The mines were first found by ancient trenches on the veins, where the "old men" had worked with stone implements. They were first tried for silver in the idea that this was what the ancient workings had been for, but were naturally found barren. Subsequently the mica on the waste heaps attracted attention, and led to systematic mining.

The mica as extracted is in the form of rough hexagonal prisms, varying in colour from silver grey and green to a rich brown—the latter, known as "rum" mica, often fetching a higher price. The arrangements for working and transport are of the most primitive description.

The prisms are split up into thin plates and cut to various patterns.

Occasionally the blocks are very large, when they become valuable. One is reported to have been 6 feet long by 3 feet wide.

The cut mica, after careful trimming, is put up in pound packages and marketed. The waste is very great, 100 lbs. of block yielding only about 15 lbs. of cut mica. The scrap is screened to free it from sand, etc.; it is then ground and used in various industries.

G. E. C.

THE MAGNETIC ORE-CONCENTRATION WORKS AT MAIERN, TIROL.

Die Erzaufbereitung in Maiern mit besonderer Berücksichtigung der Elektromagnetischen Extraction. By JOSEF BILLEK. *Oesterreichische Zeitschrift für Berg-und Hüttenwesen*, 1893, vol. xli., pages 39-44.

This mill was erected to concentrate galena, blende, and iron ores. The separation of these minerals is effected partly by the ordinary wet process and partly by magnetic means. The zinc blende is found intimately associated with siderite (carbonate of iron) which minerals having very similar specific gravities, cannot be separated by the wet method, the specific gravities being zinc blende, 4.0; and siderite, 3.6. A system of magnetic separation is therefore adopted, and the ore is roasted so as to change the siderite into magnetic oxide of iron.

The ore from the mine is separated into three classes:—1. Galena and blende ore, rough ore (*erzwände*). 2. Smalls (*grubenklein*). 3. Blende ores (*blende mittelerze*). The blende, which constitutes the main portion of the production, is found in two varieties; soft coarsely crystallized blende, containing on an average 57 per cent. of zinc, and hard blende, with which siderite, magnetite, and galena are associated, containing 40 per cent. of zinc.

The ore as it comes from the mine is first passed through a stone-crusher, which crushes in 10 hours from 45 to 70 tons to an average size of 1.77 inches (45 millimetres). The larger size, above 0.63 inch (16 millimetres) is hand-sorted, and the product may be quantitatively classified as follows:—

					Per Cent.
Best blende	...	...	...	...	1.5 to 2
Lead ore	...	...	...	...	3.5 „ 4
Blende ore	...	...	...	...	70 „ 80
Waste	...	...	...	...	20 „ 25

The cost of hand-picking is 35 to 50 kreuzer (7d. to 10d.) per ton of crude ore. After the lump ore has been hand-picked, the ores are farther reduced by rolls, and are sorted according to size by means of revolving sizing-drums preparatory to jigging. The ores are sized into particles from 0.04 to 1 inch (1 to 25 millimetres).

The jigs treat per 10 hours on an average as follows:—Fine jigs, 2½ tons of ore; coarse jigs, 7 tons of ore.

In order to render the siderite magnetic, the mixed blende and iron ore is roasted in kilns, which have an inside width of 3·28 feet (1 metre), length of 6·56 feet (2 metres), and height of 7·54 feet (3·2 metres). The carbonate of iron (Fe CO_3) is changed into oxide of iron ($\text{Fe}_2 \text{O}_3$). Each kiln roasts $7\frac{1}{2}$ tons in 24 hours. After the first heating of the furnace no fuel is required, as the combustion is kept up by the sulphur in the ore.

The roasted ore is crushed by rolls, of which there are five pairs, each having a diameter of 18·9 inches (48 centimetres), and a width of 12·6 inches (32 centimetres) and making 30 revolutions per minute. The ore is crushed to four sizes, 0 to 0·02, 0·04, 0·08, and 0·12 inch (0 to 0·5 millimetre, 1, 2, and 3 millimetres). The dust made in crushing is crushed off by two Challenger ventilators, diameter 3·94 feet (1·2 metres), width 0·92 feet (0·28 metre) which is capable of carrying off 1,400 cubic feet (400 cubic metres) of dusty air when making 300 revolutions per minute.

The dust is collected in a suitable chamber. The separation of the blende from the iron is carried out by four magnetic machines, which are supplied with electricity by two dynamos, giving 50 ampères and 31 volts. The magnetic separating-machine consists of a revolving brass drum, inside which, and at one side of the drum, are fixed magnets. The ore is fed continuously at the outside of the revolving drum where the magnets are, and the iron is attracted by the magnets and falls into a compartment situated farther from the feed than that into which the blende falls. Twenty ampères is the maximum current allowed to each separating-machine. Each machine treats $1\frac{1}{2}$ tons of coarse ore and 1 ton of the fine ore per hour.

The blende is sometimes passed a second time through a magnetic separating machine, and is finally re-jigged to get rid of any gangue (slate, quartz amphibole, etc.) The cost of working is as follows:—

				Per Ton Treated.		Per Ton of Product.	
				s.	d.	s.	d.
Roasting ...	...	...	...	0	7·6	1	9·8
Crushing and sorting ...	...	...	...	0	6·0	1	5·0
Separation (magnetic) ...	...	...	...	0	6·7	1	7·2
Jigging ...	...	...	...	0	7·2	1	8·0
Total ...	...	...	...	2	3·5	6	6·0

The following tables show the amount of ore treated, and the product in 1891:—

ORE TREATED.

			Tons.	Percentage of	
				Zinc.	
1. Smalls (<i>grubenklein</i>) ...	...	...	2968·2	...	25
2. Rough ore (<i>erzwande</i>) ...	...	...	4576·1	...	24
3. Blende ore (<i>blende mittlererze</i>) ...	...	...	3223·8	...	27

PRODUCT.

Class of Ore.	Picked Ore.			Blende Concentrates.			Lead Concentrates.			Blende Ore.			Lead Ore.		
	Tons.	Zn.	Extraction.	Tons.	Zn.	Extraction.	Tons.	Pb.	Extraction.	Tons.	Zn.	Extraction.	Tons.	Pb.	Extraction.
1. Smalls ..	55·1	48·5	1·9	956·1	46·0	32·2	2·3	68	0·08	838·0	27	28·2	82·6	7	2·8
2. Rough ore	74·2	46·5	1·7	—	—	—	—	—	—	3,476	27	75·9	169·4	7	3·7
3. Blende ore	—	—	—	1246·0	43·5	38·6	2·4	68	0·07	—	—	—	—	—	—

W. F. W.

THE CONKLING MAGNETIC ORE-CONCENTRATOR.

Ore-Dressing by Electricity at the Tilly Foster Mine. By F. H. McDOWELL Transactions of the American Institute of Mining Engineers, 1890, vol. xix. pages 71-73.

The results of a six months' trial of the Conkling electric-magnetic separator are given. The local difficulties were great. Only about two-thirds of the waste-heap is ore, and this varies in content of iron from 20 to 28 per cent. In addition, the heap was originally located without reference to further treatment, and now can only be handled by means of a locomotive operating over heavy grades. The mineral is so widely and finely disseminated through the ore that it has been necessary to resort to fine-crushing.

The process includes crushing the ore by a Blake rock-breaker on the heap, removing it in train-loads to the bins in the mill, passing it under two ball-stamps provided with screens of $\frac{1}{4}$ inch mesh, elevating it to the Conkling electric separating belts, and delivering the concentrates to the wagons and the tailings to the settling-reservoirs.

In six months there were treated 18,058 tons of lean ore, giving an average of 3,009 tons per month; this produced concentrates amounting to 6,236 tons, so that 2.89 tons of crude ore were required to produce 1 ton of concentrates. The average cost of treatment, including preparing the ore and getting it to the mill and disposing of the tailings (which items make up one-half the labour charge) was 9.375 shillings per ton of concentrates. The actual expenses in the mill averaged 6.75 shillings per ton of concentrates.

Several conclusions are drawn from the results obtained, the chief one being: Unless the location and other conditions are exceptionally favourable, it will not pay to erect works to treat the material of waste-heaps carrying less than 25 per cent. of iron.

H. W. H.

MAGNETIC CONCENTRATION OF IRON ORE.

By HARVEY S. CHASE. Technology Quarterly (Boston), vol. v., pages 64-69.

The paper deals with the separation of low-grade magnetic oxide, as found in great veins throughout the Appalachian range. The ore is reduced by repeated crushing, usually by rolls, to a fineness which generally varies between 4 and 16 mesh. Finer crushing, even up to 50 mesh, is sometimes necessary; but although an excellent product is often obtained in such cases, it is doubtful to what extent ores which require such fine crushing can be made to pay. The author adopts the plan of a preliminary coarse crushing and separation into heads for shipment, tailings, which are thrown away, and one or more grades of middlings for subsequent re-crushing and re-concentration.

The Chase magnetic ore-concentrator, consists essentially of a spirally-wound magnetic wheel, around which the crushed ore is carried by a canvas belt; worthless tailings are thrown off by centrifugal force, and the remainder is carried round to the under side of the wheel. Thence the belt passes under another magnet, with poles of varying strength and distance, by which the particles are made to rotate and tumble around each other. In this stage the middlings are separated into the number of classes desired, and the heads are carried along the belt to another smaller magnetic wheel, where the dust is removed by a current of air or water, and the ore passes thence on to the bin. The machine works either dry, or wet in a water-tight tank, the former giving quicker, the latter better, results. Some ores are best adapted for working dry, and others wet.

G. E. C.

THE TREATMENT OF TAILINGS BY THE LÜHRIG SYSTEM.

Description of the New Concentrating Plant of the Himmelfahrt Mine, near Freiberg in Saxony. By O. BILHARZ. Special Report of the Department of Mines, Victoria, 1892, 18 pages, 3 plates.

The Lührig concentrating plant at Himmelfahrt, near Freiberg, Saxony, which has been in operation since 1889, is arranged in two equal and distinct portions, so as to admit of the separate treatment of ores from different parts of the mine, or of dressing ores from other mines. Its full capacity is about 140 tons per day, the average output from the Himmelfahrt mine being rather above this figure; but about one-fifth of the ore is separately treated by dry stamping and hand-picking, so that the average quantity of ore passing through the concentrating plant is about 118 tons per day.

The ore, which is first roughly separated by hand, consists chiefly of galena, iron and arsenical pyrites and blende, in a gangue of gneiss.

The galena contains generally from 49 to 55½ ounces of silver per ton, and as a rule is richest when fine-grained. The iron pyrites and arsenical pyrites contain no silver; the latter is separated as an ore of arsenic. The blende contains a high percentage of iron; and its specific gravity is very nearly that of the iron pyrites. Separation, therefore, even with the best classification and jigging, is very difficult; and the blende ores are, as far as possible, separated by hand and treated by themselves.

The main principles, to carry out which the plant was designed, are:—

- (1) Disintegration of the ore step by step, with concentration at each stage.
- (2) Effecting crushing and concentration as far as possible with rolls and jigs, rather than stamps and slime apparatus, so as to avoid the greater loss in the latter.
- (3) Automatic working throughout.

It is hardly necessary to point out that these principles are in no way novel.

The situation chosen not giving slope enough for the latter purpose, it was necessary to erect the main building in several storeys, the ore being raised by a lift from the tramway leading from the mine.

The main building, constructed for the roll and jigging work, consists of four working-floors. The ore, in trucks containing about 2½ tons each, is raised by the lift to the top floor, and there tipped into hoppers according to its quality. Thence it passes over a sort of shaking sieve which lets the smalls through and feeds the larger pieces into stone-breakers, whence, together with the above smalls they go on to sieve-drums and, after sizing, to jigs. The outfall from these sieves falls upon moving inclined picking-bands, where the pure ore is picked out, and the drudge passes on. This then goes through three sets of rolls, each with its arrangement of sieves, jigs, etc., the whole process being nearly automatic. The waste from the jigs is run by means of a launder to a building outside, and is sold as building-sand, gravel, etc.,

The mixed drudge resulting from the above processes is elevated into hoppers feeding 2 sets of American stamps, of 15 heads each, also situated on the lowest floor of the main building. Each stamp weighs 313 lbs., and makes 53 falls of a trifle over 1 foot per minute. The duty is 176 lbs. per head per hour, a total of 23½ tons per day, or about 20 per cent. of the whole quantity of ore treated by the plant.

The stamped ore is passed through sieve drums, then through *spitzlütten*, after classification being jigged so as to obtain the separate ores in a concentrated form.

In the final working the stuff is again passed through two more sets of *spitz-*

luten. The first set divides it into coarse, middle, and fine sand. The coarse is treated with jigs of the usual kind; the middle and fine are first concentrated in a circular pulsating-jig divided radially into compartments, and which can treat the whole of the fine sands from the plant. Finally they are passed over percussion tables or vanners with rubber band moving 13 to 14 feet and receiving about 140 percussions per minute. The second set gives very fine sand and slime; the former is concentrated by a single-sieve percussion-jig, the latter by double *spitzluten*, and both are then passed over similar percussion-tables.

The total number of men employed in and about the whole plant is 51, besides overseers. The steam-engine working the plant is of about 94 horse-power effective; and gives power for the lift, lighting by electricity, etc.

The quantity of water required is 35½ cubic feet per minute.

The tailings contain silver and lead per ton as follows:—

	SILVER.				LEAD.
	oz.	dwt.	gr.		oz.
From the coarsely-crushed grains	1	12	16	...	nil.
„ elementary jigs	0	6	12	...	„
„ round jigger	0	13	1	...	„
„ percussion-tables	0	19	14	...	326½
Deposits in settling tanks	3	5	8	...	653½

No particulars are given of the cost of erection.

In another appendix to the departmental report are given the results of various trials made with Lührig vanners on various small parcels of tailings from Victorian mines. In the report Mr. Newbery emphasizes the fact that with the Lührig system success cannot be obtained if the supply of water is insufficient; and states that Mr. Lührig prefers the old *spitzkasten* to any other form of classifier.

G. E. C.

MAROS WASHING-TABLE.

Table à laver du Maros. Traitement des roches pauvres pour pyrites riches. By — EFFÈRE. Génie Civil, 1892, vol. xxii., pages 92 and 93.

The table here described is merely a modification of the ordinary hand-dressing box often used in Hungary for concentrating auriferous pyrites, and which is similar to the grave buddle once used in Cornwall for dressing tin. It consists simply of a sloping box, at the upper end of which the heavy sand, resulting from a rough gravity-separation of the pulp from the stamps, is placed, while a gentle flow of water washes it down, the denser particles being deposited, an attendant keeping it in motion. The Maros table consists of two such boxes placed side by side, successive streams of pulp and clean water being made to flow over them alternately, so that one attendant serves for both, and the dressed product can be washed off as soon as a thin coating is deposited.

G. E. C.

RIGAUD CRADLE FOR WASHING ALLUVIALS.

Appareil de lavage des sables métallifères.—Berceau Rigaud. By — EFFÈRE. Génie Civil, 1892, vol. xxii., pages 120–122.

This is a form of cradle, without rockers, suspended from a raised longitudinal axis. The principal novelty appears to be the use of a kind of comb, fixed to the axis, which when the cradle is oscillated agitates the surface of the sand collected between each pair of riffles. Small holes are made in front of each riffle, through which the concentrated product can be withdrawn at intervals into a receptacle beneath.

G. E. C.

CASTELNAU SYSTEM OF ORE-DRESSING.

Laverie des mines de plomb argentifère de Bouillac (Aveyron). By F. DESQUIENS. Génie Civil, 1892, vol. xxii., pages 202-203, plates XIII. and XIV.

The principal features of this installation are the circular jigs and belt slime tables on the Castelnau system; which are, however, not described in much detail, and of which no drawings are given.

The ore, after passing twice through stone-breakers and over hand-picking belts, is crushed by two pairs of rolls, of $27\frac{1}{2}$ inches diameter, and with a tangential velocity of 2.6 feet per second. It is then sized by a series of 5 trommels with holes of from $\frac{1}{4}$ to 7 millimetres. The particles rejected by the first are re-crushed, and these passing through the last go to the slime-tables. The intermediate sizes go to the jigs, as to which the following figures are given:—

Diameter of Particles.			Blows per Minute of Piston.		Length of Stroke of Piston.			
Inches.		Millimetres.			Inches.		Millimetres.	
0.20 to 0.28	...	5 to 7	...	240	...	1.18	...	30
0.12 „ 0.20	...	3 „ 5	...	260	...	0.79	...	20
0.06 „ 0.12	...	1½ „ 3	...	280	...	0.40	...	10
0.02 „ 0.06	...	½ „ 1½	...	300	...	0.20	...	5

The product averages 60 per cent., and the waste 0.5 per cent. of lead. The middle product, of 10 to 20 per cent., is sent back to the rolls.

The slimes, after settling and re-mixing to the proper consistency, are concentrated on rubber endless belts with a surface of 46 by 4 feet, moving longitudinally 9.8 inches per second, and inclined in the direction of the width. Each machine is stated to concentrate 20 to 30 cwts. of ore per hour.

All the water is used over and over again, in order to avoid loss in floating slimes.

No particulars are given as to capacity, etc., of the plant.

G. E. C.

RECENT GOLD-MILLING PRACTICE IN NOVA SCOTIA.

By JOHN E. HARDMAN. Journal of the Mining Society of Nova Scotia, 1892, vol. i., part 2, page 34, and Canadian Mining and Mechanical Review, 1892, vol. xi., pages 134-137, and three plates.

The Oldham mill has 10 stamps, especially designed for hard quartz containing coarse gold, and for the conditions of custom-milling. The battery is worked by power from a Pelton wheel.

The main features of the system of working adopted are a very short rapid drop and saving of most of the gold inside the mortar. The stamps are of the Homestake pattern, full stamp with new shoe weighing 858 lbs. The modifications adopted in the arrangement are fully described in the paper.

The stamps work 85 drops of $6\frac{1}{2}$ inches per minute, the screen being the equivalent of a 30-mesh. The capacity is from 28 to 30 tons per 24 hours.

The gold is obtained in the following proportions:—On outside plates, 8.55 per cent.; on inside plates, 23.40 per cent.; and in mortar sands, 68.05 per cent.; so that 91.45 per cent. is retained behind the screen.

The tailings assayed 8s. 4d. per ton, almost entirely in the sulphides; tailings from concentrators gave 1s. 8d. to 2s. 1d. per ton.

The milling cost in the Black Hills is, according to Prof. Hofman, allowing deductions for fuel, 2s. 4d. per ton.

The costs per ton at the Oldham mill are as follows:—

	s.	d.
Labour	1	1·65
Supplies	0	1·47
Iron	0	1·32
Quicksilver	0	1·02
Total	1	5·46

When running on large lots the cost has been reduced to 1s. 2·31d. per ton. On the other hand, during the winter months an extra charge of 1·76d. is necessary for fuel to warm the mill.

G. E. C.

MINING IN SARDINIA.

Histoire de l'Industrie Minière en Sardaigne. By — DE LAUNAY. *Annales des Mines*, 1892, series 9, vol. i., pages 511-538.

Mining was probably introduced into Sardinia by the Carthaginians. In Roman times, and up to about 1860 only argentiferous galena was worked to any great extent, the silver being extracted by cupellation. The galena worked by the Romans seems to have been only in soft rocks, such as limestone, and was mined by means of very numerous narrow vertical pits. Analyses of slags and pigs of lead found prove that the silver-extraction was well performed; the slags resulting from the initial production of raw lead, however, assay as high as 25 to 30 per cent. of lead, with 70 to 100 grammes of silver to the 100 kilogrammes of lead (23 to 32½ ounces per ton).

After the retirement of the Romans, the mines remained unworked until the Pisan domination (1004-1823), when they were worked by free companies of miners. The author mentions a curious mining code relating to this period, the technical terms showing traces of German influence. In some cases the workings were carried to a depth of 800 feet (250 metres), the drainage being performed by primitive pumps. The slags show an improved metallurgical treatment compared with that of the Romans.

Early in the fourteenth century Sardinia was conquered by the Aragonese, by whom the mines were worked as State property—at a loss: subsequently they were leased to a Genoese company. From the sixteenth to the nineteenth century mining was almost extinct. Its revival resulted from the application in 1848 of a new mining law similar to the French law of 1810, and a subsequent improvement of the same in 1859. The following figures are given of the extraction of argentiferous galena:—

	Tons.
1846	17
1858	6,637
1860	15,228
1865-6	26,229

Calamine was first worked in Sardinia in 1866 at the now famous Malfidano mines, where its value was discovered accidentally after a great deal of time and money had been spent fruitlessly in the search for galena. The mines now employ 1,700 men, and produce 50,000 tons of calamine annually. Up to 1888 the total production was over a million tons.

The first lead mine re-worked in modern times was that of Monteponi. Work was commenced in 1791 and carried on by the State on a small scale. In 1850, it

was leased privately for 30 years; and shortly after yielded an annual production of two million francs, of which 20 per cent. was profit. At the renewal of the concession in 1880, much more severe terms were exacted, including the driving of a drainage-tunnel 6,600 yards (6 kilometres) long; which was completed in 1890 at a cost of £80,000 (2,000,000 francs).

The Sarrabus silver mine was first re-worked in 1870, and in 1885 yielded a value of £96,000 (2,400,000 francs). The lode is extensive and well-defined, the silver being mainly in the form of sulphide, in a calcitic gangue.

Of late years the activity of mining in Sardinia has diminished, the production both of calamine and blende showing a falling off; this is owing partly to the increased costs of working in depth, partly to the fact that the calamine-deposits are always limited masses localized near the surface. Moreover, at the Sarrabus, it seems that below a certain depth the silver disappears, at any rate temporarily.

G. E. C.

MINING IN SARDINIA.

Geognostische und bergmännische Mittheilungen über den Bergbaubezirk von Iglesias auf der Insel Sardinien. By — MARX. *Zeitschrift für das Berg-, Hütten- und Salinen-Wesen im Preussischen Staate*, 1892, vol. xl., pages 263-278.

This paper contains a description of the geological features, and of the mines of the district of Iglesias in the south-western part of the island. The formation of the district is mainly Palæozoic, and these rocks rest upon granite, which is found at the surface in only a few places. Ores are found chiefly in the granite and in the slate formation, but also in limestones of more recent age.

In the granite the ore occurs in lodes, and the principal minerals found are silver-lead, zinc blende, fahlerz, and galmei. The vein-stuff is mostly quartz.

The limestone ore-deposits consist of lead and zinc ores, and occur as stockwerks or as contact-deposits between slate and limestone. In the granite district the most important mine is the Monte Vecchio, situated on the vein of that name, which is a contact-deposit between slate and granite. The principal minerals won are galena, zinc blende, siderite, and copper pyrites. Of the limestone mines the chief is the Monteponi mine, situated close to the town of Iglesias. In 1889—6,000 tons of lead ore were raised from this mine; it formerly belonged to the Italian Government who sold it to the present company in 1880. One of the conditions of sale was that an adit should be driven to drain the mines of the district. This adit, which commences 9 feet above sea-level, is now about 17,000 yards (15,786 metres) long. The ores are brought down to the coast by a railway 9 miles (15 kilometres) in length.

At the Monteponi mine the zinc ores, which contain on an average 35 per cent. of zinc, are roasted in a reverberatory furnace, and in an Oxland calciner. Cardiff coal is used. The reverberatory furnace treats 20 tons of ore in 24 hours, using 15·11 per cent. of coal. The ore loses in roasting 23 per cent. in weight. The Oxland furnace roasts 12 tons of ore in 24 hours, using 12·41 per cent. of coal. The ore loses 21 per cent. in weight. The reverberatory requires five men to attend to it, and the working expenses per ton of zinc ore amount to 4·20 lire (3s.) The Oxland calcining kiln is worked by two men, and 1 ton of roasted ore costs 5·40 lire (4s. 3d.)

The paper also contains particulars of the methods of mining. W. F. W.

ORE-MINING IN SERBIA.

Der Erzbau in Serbien. By F. B. PFEIFFER. *Berg-und Huettenmaennische Zeitung*, 1892, vol. li., pages 2-5.

The mineral resources of Serbia, though as yet only partially developed, are very great, metallic ores of considerable variety occurring in various geological formations and in nearly all the high lands of the country. According to position they belong chiefly to the five principal districts of Kopaonik, Schumadija, Drina, Kucevo, and Zaplanina. So far as is known the Romans were the first to open mines in the country, and they were followed during the period of national independence by the Servians themselves. At present operations are conducted on a reduced scale in some only of the above-mentioned districts.

Gold is found in combination with various ores and in the sands of several rivers, and the ores of arsenic, antimony, bismuth, copper, iron, lead, manganese, silver, and of nickel and cobalt in small quantities are known to occur. Quicksilver is found in the district of Rudnik and in the Avala mountains. Silver occurs in the greatest quantities and in combination with lead forms the backbone of the mineral wealth in all the districts, the other metals occurring here and there in larger or smaller detached ore-deposits. After lead and silver, as regards quantity, come copper, antimony, and iron.

The Kopaonik mountains run from north to south for about 30 miles in the south of Serbia near the Bosno-Turkish boundary. Now covered with woods and thinly inhabited, they are rich in ruins of towns, villages, and foundries. Heaps of slag and ore abound, and it is known that during the middle ages miners from Saxony and from Ragusa frequented the district in considerable numbers. The Turkish conquest put an end to the mining industry, and although probably far from exhausted, the district is now the one least worked and least known. It is known to contain iron, lead, silver, and gold.

The Schumadija district comprises the Rudnik mountains and their spurs. Its history corresponded with that of the Kopaonik district up to the date of the Turkish conquest, after which the Turks and subsequently the Austrians carried on mining work, chiefly in lead and silver. In the Avala mountains belonging to the Rudnik range slag from old workings is found, computed at about half a million tons. The chief veins run from Rudnik northwards, silver-lead ore being the most plentiful. Copper and gold occur in small quantities, though not very pure, while in the Vencac mountains pure iron ore occurs in large quantities along with the silver-lead ore. In the Avala range quicksilver is found, and there is a vein of iron ore reaching to the neighbourhood of Belgrade. Silver occurs in all the ores of this district, hitherto proved, in large quantities. As yet no lead ore has been found to contain less than 0.2 per cent. (65 ounces per ton) of silver, and some ores have yielded as much as 0.5 per cent. (163 ounces per ton). It has been estimated that the slag-heaps from old workings lying between Paryan and Guberevac contain 55 per cent. of lead and 0.0037 per cent. of silver weighing 28,000 tons and 37 tons respectively and worth over £1,000,000.

The Drina district is also rich in ores. From Loznica on the Drina to the Tara mountains and from Lesnica to Suvobor run veins of silver, lead, and gold, accompanied in places by iron, arsenic, zinc, and copper ores. From Borina to the neighbourhood of Valjevo runs a thick and rich vein of antimony which in several places crops out at the surface. This is accompanied on the left by zinc, lead, and silver, and on the right by copper, the latter vein reaching its greatest thickness near Valjevo where it comes to the surface. The silver-lead ores of this district contain from 0.25 per cent. (82 ounces per ton) to 0.55 per cent. (180 ounces per

ton) of silver. The antimony was not worked in earlier times. Zinc occurs in large irregular blocks containing from 8 to 50 per cent. of pure metal near the village of Vasic. The whole Drina district is traversed by paths, now overgrown, and the numerous old cemeteries bear testimony to the large population that once inhabited it. The two best known ancient mining centres of the district were Zajeca and Krupanj, the latter place being at one time the centre of the iron industry of all Servia.

The ore district of Kucevo comprises the mountains in Eastern Servia which form a continuation of the Siebenburg and South Hungarian Carpathian mountains, through which the Danube has broken the passage of the Iron Gate. The same formations occur on both sides of the river. The principal mines now at work are the Kucajna and Majdanpek. The Kucajna numbers lead, silver, and gold among its ores, the Majdanpek lead, iron, copper, silver, and gold. The Kucajna ores are the richest in gold and silver in all Servia, containing, as they do, 0·07 per cent. (22 ounces per ton) of gold and 0·75 per cent. (245 ounces per ton) of silver. This district was also worked by the Romans, as by later masters of the country in succession.

The Zaplanina district contains the mountains between the Nisava and the Binacka-Morava. Its mineralogical features are now little known, but there are many traces of the existence in earlier times of a busy mining industry. Veins containing iron, copper, and silver crop out in various places, and gold occurs in the rivers. The river-beds were searched for gold in olden times; and even now, gipsies do a little gold-washing, although it is forbidden by law.

A. R. L. and W. F. W.

MINING AND METALLURGY IN CHILI.

Le Chili Minier, Métallurgique, Industriel. By CH. VATTIER. Mémoires de la Société des Ingénieurs Civils, 1892, vol. ii, pages 37-140, and plate LXVII.

The raw nitrate earth as extracted in the Tarapacá and Taltal districts, varies in contents from 20 to 40 per cent. of pure nitrate. The average cost of extraction is about 25s. per ton (70 centavos per quintal of 100 lbs.) With raw nitrate of 50 per cent. 1 quintal of coal is required to produce 12 of pure nitrate. The cost for rail carriage (66 miles) is 13s. per ton (37 centavos per quintal).

Gold is found both in alluvials and lodes. Among the latter are cited those of Guanaco in Taltal, where the vein-stone consists of quartz and barytes, often crystalline and transparent, with spangles of gold. In the province of Coquimbo many lodes are worked, the yield rarely exceeding 11-14 dwts. per ton.

The principal silver-mines worked are situated in the north, especially in the provinces of Antofagasta and Atacama. Those of Copiapo, which produced largely some forty years since, are now mostly worked out. In the province of Santiago are situated the well-known mines of Las Condes.

The copper-mines of northern and central Chili constituted for a long time the principal mineral riches of the country. The production nearly forty years ago was one-third of that of the whole world, whereas it is now less than one-fifteenth. At first only the oxidized ores were worked, the sulphides being rejected; during the last half century, however, the sulphide ores having given the bulk of the output. The principal centre of production is the province of Coquimbo.

Chili is exceptionally rich in deposits of iron ore of high quality, often situated under conditions very favourable for working and transport; they are especially abundant in the provinces of Atacama and Coquimbo. As yet they have only been

where they are concentrated and smelted or fused for smelting other ores. The average production of sulphur is about 25,000 tons per year. Very little attention has been given to the sulphur deposits which are known to exist in the vicinity of Antofagasta.

The principal sulphur deposits are situated in the neighbourhood of Antofagasta, and consist of a natural sulphur containing percentage of manganese 25 per cent. and iron 10 per cent. with 5 per cent. percentage of lime 9 per cent. per cent. of soda 10 per cent. and phosphorus 10 per cent. As a rule both the iron and the manganese are present in a small degree, and in some cases it may reach as high as 10 per cent. of iron.

The principal sulphur is obtained by smelting either in reverberatory furnaces or in blast-furnaces. Work is not yet smelting only in Copiapo and a few other localities in the north. The ore is transported to the furnace, and the product is sold at 10 pesos per ton. At Warhuas in Santiago, the dry wood used for the furnace is sold at 15 pesos per ton (15 to 16 pesos) per ton. In the case of smelting wood can be produced at less than 10 pesos per ton. Charcoal used in smelting sulphur is sold at 10 pesos per ton. It could be made in the north and south of Chile at 10 pesos per ton.

The Chilean sulphur is obtained mainly from the deposits of other deposits exist in the north and south of Chile. The present production is 600,000 tons per year, and is still increasing. The price per ton is now about 16s. to 18s. per ton. The sulphur is obtained in the northern ports. The beds are near the coast and vary in thickness from 1 to 3 feet. They are often worked for considerable distances under the sea. The same may be said for accidents are rare.

The following are analyses of sulphur from Chile —

Water	...	50	...	45
Volatiles matter	...	40.2	...	40.8
Fixed matter	...	33.2	...	45.2
Clay and ferruginous ash	...	1.6	...	6.2
		100.0		100.0

Calorific power as compared with pure carbon 75.5 and 71.3. Foreign coal, being brought as return freight at low rates, costs only 5s. to 5s. (2 to 3 pesos) more per ton than the lignite. The foreign coke used for smelting costs from 46s. to 52s. (25 to 33 pesos) per ton, and anthracite from 27s. to 33s. (17 to 21 pesos) per ton delivered.

Silver ores are in Chile treated either by amalgamation or by smelting in low blast-furnaces. The former is now performed by a method known as the Kronke process, the old patio process having long been abandoned. This process appears to consist of the addition of chemicals, notably salt and sub-chloride of copper, during amalgamation.

The small amount of lead in the ores, and their siliceous nature, necessitate many special features in the smelting process adopted, which is described in great detail. In the smelting mixture a great deal of slag and fluxes are necessary, generally nearly half the total charge exclusive of coke; the coke consumed is 25 per cent. or more of the actual ore smelted. The ore must be in lumps; fines or dust must be made into briquettes, and even then used sparingly. The average quantity smelted will be, with ordinary ores, 10 to 12 tons per day. The product is a copper-lead matte, containing generally about 30 to 35 per cent. of copper, 16 to 18 per cent. of lead, and 0.1 to 0.3 per cent. of silver. Some argentiferous lead is produced at the same time; which, after re-smelting, contains 90 to 92 per cent. of lead, with 0.8 to 1 per cent. of silver.

The average assay of copper ores, as sold to the smelting-works, is about 12 to 14 per cent., but in special cases it is much higher or lower. In some parts of Chili, in the centre and south especially, there are many small reverberatory furnaces worked by the landed proprietors, using wood as fuel, and producing a 50 per cent. matte at one operation. This is broken and roasted in heaps, and when sufficient is collected it is re-smelted to bar copper in the same or a similar furnace. These furnaces smelt 3 or 4 tons per 24 hours, using 10 tons of wood costing 3s. to 5s. (2 to 3 pesos) per ton: and, in consequence of the growing scarcity of wood, they tend to disappear.

The greater part of the Chilian copper is however smelted in reverberatory furnaces with foreign (English or Australian) coal or native lignite, by the ordinary Welsh process, producing 50 per cent. matte. This is broken, crushed, roasted, and re-smelted with oxide ores and slags, yielding some copper bars and some white matte of 70 to 72 per cent. The latter is re-roasted, made into rosette copper and refined. The 50 per cent. matte is, at Lota, Bessemerized direct.

In these reverberatory furnaces about 1 ton of coal is necessary to smelt 2 or 3 of ore; and the slags from the first fusion assay 0.75 per cent. on the average. Many of these works are situated in the province of Coquimbo, where the Guayacan works have produced as much as 1,000 tons of copper per month. Still more are found farther south in the coal region, where the ores are mainly imported from the north. The Lota works have produced up to 12,000 tons per annum of copper bars.

A good deal of ore, especially away from the coast, is smelted with coke or anthracite, in low blast-furnaces (*fours à manche*) much resembling those used for silver ores. The method of smelting at the Maitenes works, province of Santiago, is described. The ore averages 18 to 25 per cent.; it is a double sulphide of copper and iron, and the gangue is quartzose. It is screened, and the coarse portion roasted in heaps of 200 to 300 tons. The fines are made into briquettes and roasted, but this operation at present is difficult. The coke used is 13 per cent. of the ore weight. Each furnace smelts from 20 to 25 tons of ore (besides fluxes, etc.) per 24 hours. The slag assays under $\frac{1}{2}$ per cent., and the resulting matte about 50 per cent.; it is led directly into a converter, where it is transformed into copper bars. Each converter produces 4 to 5 tons of copper per 24 hours.

At the works of the Panulcillo Company 308 tons per month are produced of 50 per cent. matte, from a very poor ore with a garnet-rock gangue.

The author strongly advocates the creation in Chili of a steel-making industry, for which he says every facility exists, either by using coke made from the lignite (if the latter will admit of it) or charcoal from the southern forests.

G. E. C.

PROGRESS OF THE METALLURGY OF NICKEL.

Les Progrès de la Métallurgie du Nickel, etc. By D. LEVAT. *Annales des Mines*, 1892, series 9, vol. i., pages 141-226.

The only nickel-ore deposits of known first-rate importance are those of New Caledonia and Sudbury in Canada. In New Caledonia, nickel occurs only in the form of hydrated magnesian silicate, apple-green in colour when pure, in fissures in serpentine; and it must clearly have been originally deposited in this state, sulphides or arsenides being unknown, even in the deepest workings. The serpentine forms about half the area of the island, especially towards the south: the nickel being always found at or near its junction with funnel-shaped pipes (*vasques*) of red clay, although never in the clay itself.

This clay is formed by the hydrothermal alteration of the serpentine; numerous fissures in which, bearing north-west and south-east, or roughly at right-angles to

the general direction of the wind, have given passage to metaliferous springs carrying iron and manganese, which have eaten away the serpentine, and deposited their load of red matter in the fissures so produced. The manganese, always containing iron, is found as veins in the clay, and the iron sulphides having finally predominated, near masses of granular hydrated hematite have been deposited on the top of the clay. The hematite is in the form of hydrated oxide, without any trace of sulphur or arsenic, and the mineral extracted rarely contains more than 25 to 3 per cent. of metallic iron.

In the south of the island the serpentine contains many grains of chrome iron, which have been re-arranged in an enriched form in the clay.

After the formation of the clay-*gossiers*, fissures and cavities have been produced between the clay and the surrounding serpentine: which, together with the fissures and joints in the serpentine itself have been subsequently filled with the deposits from metaliferous solutions, forming a breccia, which constitutes the nickel ore. The deposits are therefore either *stockwork*, contact deposits between the clay and serpentine, or the fillings of fissures in the serpentine near the clay: these last being generally more concentrated and therefore more valuable.

The *stockwork* are worked as open-castings: and it is very important in commencing to not only remove the red clay without allowing it to mix with the nickel ore—first, because the grains of iron-ore which it contains cannot be separated easily by washing from the nickel, and much impoverish the matter: and, secondly, because the highly aluminous clay renders the mineral already very siliceous, still more refractory. This mode of working is very troublesome during the rainy season, particularly as the labour supply is small.

The ore is divided into two classes—that containing over 5 per cent. of nickel, and *poorer ore*. It is then brought down to the plains for washing, which consists in merely separating the red mud: owing to the equal density of the ore and gangue, no further concentration is possible, and all ore of 3 to 4 per cent. and under has to be thrown away.

The mineral as extracted varies greatly in composition, but the following may be taken as extreme analyses:—

	Per Cent.	Per Cent.
Silica	45	50
Iron	16	14
Nickel	8	7
Magnesia	12	10
Alumina	3	5
Water and oxygen ...	16	14
	100	100

This composition necessitates an addition of 25 to 30 per cent. of bases, and more or less sulphides, the smelting mixture being made up as follows:—

	Owts.
Ore	20.0
Coal	6.0
Sulphur	0.7
Fine coke	1.5

The high cost of coke, and the want of experienced labour for smelting, has caused the concentration of the ore to a matte on the spot to be temporarily suspended. It is now principally treated in England in small water-jacket furnaces running through 25 to 30 tons of ore-mixture per 24 hours, soda-ash being used as a flux. The coke used is over 30 per cent. by weight of the ore, and the resulting matte averages 50 to 55 per cent. of nickel, 25 to 30 per cent. of iron, and 16 to 18 per cent. of sulphur.

At Sudbury, in Ontario, Canada, nickel is found in association with magnetic iron pyrites, accompanied by chalcopyrite—the mines having been first worked for copper only. The mineral occurs in large lenticular masses, interstratified with gneiss of the primitive formation of North America—here over 3,000 feet thick. The beds have been greatly contorted, lying at steep angles up to 70 degs., with a general strike of north-east and south-west: and they are frequently penetrated by dykes of diorite, the deposits of magnetic pyrites occurring at or near the contact, sometimes even in the diorite itself—which forms, moreover, the gangue of the ore.

The average assay of the ore rarely exceeds 3 to 4 per cent. of nickel, and about the same of copper, but it appears to become enriched in depth. The following is an average analysis of the ore picked out for copper:—

Sulphur	...	...	...	...	26.72
Copper	...	...	...	...	12.61
Iron	...	...	...	...	29.22
Nickel	...	...	...	...	3.12
Protoxide of iron	...	...	...	...	6.22
Lime	...	...	...	...	4.84
Magnesia	...	...	...	...	2.61
Alumina	...	...	...	...	2.63
Silica	...	...	...	...	13.06
					101.03

According to Messrs. Peters and Garnier, the deposits may be divided into two classes:—(a) Those such as the Stobie and Leighton mines, composed of almost pure massive magnetic pyrites containing little copper or nickel, but which after roasting form a good flux for the richer ores. These deposits are worked by open-cutting. (b) The deposits of more elongated lenticular form, worked by means of shafts following the dip. On an average the ores from these deposits (Copper Cliff mine, Evans mine, Blizzard mine, etc.) contain 3 to 5 per cent. of nickel and as much copper. All these ores are trammed direct to the roasting-floors, the cost delivered being about 8s. (10 francs) per ton, with about 50 per cent. of ore of the first class. The roasting is done in heaps, costing about 2s. 6d. (3 francs) per ton; a heap of 500 or 600 tons taking 50 or 60 days to roast. The roasted ore is smelted in large water-jacket furnaces, with a coke consumption of $12\frac{1}{2}$ per cent. of the weight of ore; the matte produced being about 12 per cent. of the charge, and the slags assaying 0.45 per cent. of nickel and 0.40 per cent. of copper. Originally the matte was considerably richer in copper than in nickel, which greatly lessened its value: in 1889 the matte of the Canadian Copper Company ran 26.9 per cent. of copper and 14.1 per cent. of nickel; but in February 1891 this had been reduced to 16.9 per cent. of copper against 21.5 per cent. of nickel. The matte produced by the Dominion Mineral Company, who are able to mix their ore with purely nickeliferous mineral from other mines, averages 18 to 20 per cent. of copper to 24 to 26 per cent. of nickel.

Coke costs about £1 8s. (35 francs) per ton delivered at the furnaces; and the average cost of smelting in the large water-jackets of 120 tons per 24 hours' capacity, may be taken at 6s. to 7s. (8 to 9 francs) per ton.

The paper includes a very complete account of the metallurgy of nickel; but the author merely refers to the considerable nickel-deposits of Norway, which occur under very similar conditions to those of Canada, and which have been largely worked during the last twenty-five years.

G. E. C.

THE PRODUCTION OF NICKEL.

Om verdens nikkelproduktion og om konkurrence-betingelserne mellem de norske og de udenlandske nikkelforekomster. By J. H. L. VOGT. Geologiska Föreningens, Förhandlingar, Stockholm, 1892, vol. xiv., pages 433-475.

The Sudbury (Canada) deposits of nickeliferous pyrites are—as is also the case in Norway—situated in gabbro, and are often concentrated at its contact with other rocks; they are mineralogically and geologically similar to the Norwegian deposits. As in other cases, the nickel carries with it a little cobalt, generally about one part cobalt to five to ten nickel. The accompanying copper is also considerably more than in Norway and Sweden.

Nickel ores are of three kinds :—

Arsenides.—Found chiefly in lodes, and which up to the middle of the century formed the chief source of supply, from Germany and Austria-Hungary.

Sulphides.—As found in Canada, Norway, etc.

Silicates.—As worked in New Caledonia, etc.; and deposited by lateral secretion from serpentine containing a little nickel. In New Caledonia the garnierite occurs intimately associated with asbolite, and seems to have been derived from the same solutions; the latter being deposited first, probably because its component elements were easier to oxidize.

The author gives a table showing the world's production for the last half-century: rising from 100 to 250 tons yearly in 1840 to 1860, to 600 to 700 tons in 1870 to 1880, and 1,250 to 1,500 tons in 1888 and 1889. He estimates the production of 1890 at about 2,000 tons, and that of 1891 and 1892 still higher; but considers the figures given by Mr. Levat* to be excessive.

Details and tables are given of the output in the various producing countries, especially as to Norway, Germany, and New Caledonia.

He states the average contents of the Norwegian nickeliferous pyrites as 3 to 4½ per cent. of clean mineral. Of course the smelting-ore is much poorer, having averaged up to 1880 only about 1 per cent., and has since varied from 1·4 to 2·3 per cent. The garnierite mixture of New Caledonia averages of late years from 6 to 8 per cent.

There are also tables giving the fluctuations in price from 1867, when it was worth 8·10 kroner (say 9s.) per kilogramme, to the present value (at the date of the paper) of 3·50 to 4 kroner (say 4s. 5d.). Between 1873 and 1875 the price rose to 20 and 24 kroner (£1 1s. to £1 6s. 8d.). The rise which then reached its apex was owing to the demand for coinage purposes; the subsequent rapid fall being caused by the working of the New Caledonia deposits.

According to Mr. du Peloux the cost of production per kilogramme in New Caledonia of metallic nickel was (1880) 5s. to 6s. (6 to 7 francs), which could be reduced to 3s. or 4s. (4 to 5 francs). The author asserts that the cost in the best Norwegian works is 1·50 to 2 kroner (1s. 8d. to 2s. 3d.), including all costs for bringing up to a 50 per cent. matte; and gives Mr. Levat's authority for an estimate of the cost at Sudbury (Canada) as 2 francs per kilogramme in a 20 per cent. matte (not charging any of the cost to the copper contained in it). At this rate the costs of production would be nearly equal, the higher grade of the Canadian ore being counterbalanced by the higher prices for labour and materials. G. E. C.

* *Annales des Mines*, 1892, vol. I., page 141.

NICKEL MINES OF NEW CALEDONIA.

Étude sur les Mines de Nickel de la Nouvelle-Calédonie. By FÉLIX BENOIT.
Bulletin de la Société de l'Industrie Minérale, 1892, series 3, vol. vi., pages 753-804.

An historical account is given of the discovery of nickel in New Caledonia by Mr. Jules Garnier, and of the subsequent development of the industry.

The deposits are found in the serpentine formation which constitutes the greater part of the south of the island. The mountain crests of this formation, on which they occur, run about north-west and south-east, or in the direction of the length of the island; their sides are covered by sheets of red clay surmounted by masses of iron ore.

The deposits consist entirely of hydrated magnesian silicate (garnierite), varying in colour from green to chocolate, soft and often unctuous to the touch. The composition is extremely variable, but the average is stated as follows:—

	Per Cent.
Nickel	7
Magnesia	26
Iron	12
Silica	45
Water... ..	10

The serpentine itself nearly always contains traces of nickel, said to vary from 1 to 5 per cent.

The nickel ore is always enclosed in serpentine, at or near its contact with the red clay. It occurs generally in very irregular fissures, often forming a kind of stockwork; but sometimes in definite almost vertical veins, or in masses. Many of the deposits are worked in the open. There is no gangue, as a rule.

The deposits are situated along definite lines of enrichment, starting from the east coast and running in a south-west direction; and at present only those near the coast are worked. The nickeliferous veins as a rule diminish in size in depth, but to this there are exceptions.

There is nothing worthy of note in the methods of working, either by levels or open cut. The mines are generally situated at a considerable elevation, averaging 1,500 feet, and the ore is transported from the principal mines, by inclined planes or aerial tramways.

The labour employed consists of the three following classes:—

- (1) English miners, paid 6 to 9 francs (5s. to 7s.) per day.
- (2) Kanakas, receiving 20 francs (16s.) per month, with keep.
- (3) Convicts and other prisoners hired from the State.

The author strongly advocates the importation of free miners from France.

The cost of mining varies from 15 to 40 francs (12s. to 32s.), and that of carriage to port from 0.50 to 10 francs (5d. to 8s.) per ton. The value at port of shipment for ore of $7\frac{1}{2}$ to $8\frac{1}{2}$ per cent. nickel is 105 francs (£4 3s. 4d.), and ore of $9\frac{1}{2}$ to $10\frac{1}{2}$ per cent., 125 francs (£4 19s.) per ton; the assays being calculated on the ore when desiccated. The freight to Europe is from 40 to 50 francs (£1 12s. to £1 19s. 6d.).

Thio District.—The author next proceeds to describe the mines at work in great detail, commencing with those belonging to the French Company Le Nickel. This Company works eleven mines situated in the Thio district, which he divides into three groups; all are worked as open cuts, and they together employ 1,500 hands.

The first or Plateau group comprises five mines, together producing 2,500 tons monthly of ore averaging 7 per cent., a production which it is stated might at once

be raised to 4,000 tons per month if sufficient labour were available. One mine is worked to a depth of 300 feet. The whole mountain in which they are situated is said to be probably a stockwork.

The Pauline group comprises two mines, both of stockwork type, producing together 500 tons monthly of 5 to 6½ per cent. The Pauline mine is situated in greenish serpentine of porphyritic appearance, the alteration of which shows a definite line up to which the nickel-bearing solutions reached.

In the third or Stilling group the ore is friable, varying in colour from yellow to brick-red, so that it is difficult to distinguish it from the clay previously mentioned. The production of this group is 300 tons per month, averaging 7 per cent. nickel.

Nakéty District.—The Bienvenue mine is worked on a well-defined vein running north-west and south-east, and dipping regularly 80 degs. to the west, the workable thickness of which varies from 10 inches to 2½ feet. Both walls (serpentine) are well-defined, with slickensides. The nickeliferous filling varies in colour from green to chocolate-yellow, and black at the lowest level. This mine produces 300 tons per month of 8 per cent. ore.

The Barbouillée and Boulangère mines, both worked as open cuts, produce together 200 tons of 6 per cent. ore per month.

Canala District.—The workings of the Boakaine mine are on a mass of rich green ore apparently formed by the union of a number of small veins. It produces 250 tons per month of 8½ per cent. ore, and belongs to the Le Nickel Company.

Couaoua District.—The Dorée mine is worked by four levels; the ore being quartzose in the upper level, and magnesian in the lower ones. It produces 350 tons of 6 per cent. ore per month, which with additional labour could be easily increased.

The Caulry group are worked by quarries and mines on deposits, which in depth concentrate from stockworks into definite east-and-west lodes, coinciding in strike with the crest of the mountain in which they are situated. Their production is 300 tons per month, averaging 9 per cent.

The other principal districts are those of Bourail, Paouéa, and Kouiambo. It is estimated that the total production for 1892 will reach 100,000 tons. G. E. C.

PRODUCTION OF NICKEL IN THE UNITED STATES.

Nickel. By W. R. INGALLS. *The Engineering and Mining Journal* (New York), 1892, vol. liii., pages 40-41.

Occurrence.—In the United States there is but one deposit of nickel which has been mined regularly for that metal alone, it being located at Lancaster Gap, Penna. The lead ores of South-eastern Missouri carry a small amount of nickel, in conjunction with cobalt, both of which are recovered as bye-products.

Production.—The following figures show the production of nickel in the United States, together with the imports into the country and the exports from it, for the years 1890 and 1891:—

		Production.					Value of		Value of	
		Amount.	Average Price.			Value.	Imports.		Exports.	
		Lbs.	s.	d.	...	£	£	...	£	...
1890	...	200,332	...	2	8	...	26,694	...	77,137	...
1891	...	144,841	...	2	5½	...	17,816	...	—	...

The exports of nickel from New Caledonia in 1890, according to a recent consular report, amounted to 3,300 lbs., and of nickel ore to about 5,000 tons, which, averaging about 8 per cent. of nickel, was equivalent to about 882,000 lbs. of metallic nickel, representing a total export of 885,300 lbs.

The production of nickel (in nickel-copper matte) in Canada in 1890 was 1,336,627 lbs., that being the first year for which statistics of the Sudbury district were published.

Methods of Nickel Winning.—The nickeliferous chalcopyrite and pyrrhotite of Sudbury, Ontario, are first roasted and then smelted in cupola-furnaces to nickel-copper matte, containing about 20 per cent. of nickel.

These mattes are very refractory, and had not been successfully handled until the year 1891. Of the large output in the Sudbury district in 1890 but a small portion was shipped. In the latter part of that year the Orford Copper Company devised a successful method of refining these mattes, and since then the bulk of the output of the Canadian mines has been brought to the United States, the Orford Copper Company now being the largest nickel refiner in the world. By the secret process used by this company, the copper and nickel in the matte are separated and the nickel converted into nickel oxide, which is said to be more suitable for the manufacture of nickel-steel than metallic nickel. A small part of the Sudbury mattes is sent to Swansea to be refined.

There are three nickel-smelting and refining works in the United States, viz., the American Nickel Works, at Camden, New Jersey, the works of the Orford Copper Company, at Constable's Hook, New Jersey, and the works of the Canadian Copper Company, near Cleveland, Ohio, which are not yet completed. The American Nickel works use ore from the Lancaster Gap mine, Canadian mattes, and ore from South-eastern Missouri. The Orford works run exclusively on Canadian mattes, whilst the Cleveland works are to use mattes from the Canadian Copper Company's mines at Sudbury, Ontario.

The Nickel Market.—The consumption of nickel has greatly increased, the increase being due principally to the growing demand for the metal for use in the manufacture of nickel steel, the Creusot works (in France) alone having contracted for a large part of the product of the *Société du Nickel*, while the United States Government purchased the large quantity of 6,500 tons of Canadian matte, containing probably about 20 per cent. of nickel. There has also been an increased demand from the nickel-platers, the German-silver manufacturers, etc.

The United States Government (1891) made elaborate tests of nickel-steel and other kinds of armour-plate at Indian Head, Maryland, which resulted in a decisive approval of the nickel-steel, and it has now been adopted as the protective material for the new cruisers and battle-ships.

J. W.

THE HUANCHACA MINES, BOLIVIA.

Notes on the Huanchaca Mine, Bolivia, South America. By ROBERT PEELE, JUN.
School of Mines Quarterly (New York), vol. xiv., pages 152-155.

The mines are situated in a group of hills on the Central Bolivian plateau, 13,400 feet above sea-level, and are connected with the Chilean port of Antofagasta by a 30-inches gauge railroad, 395 miles long. The workings are on two parallel and nearly vertical veins, cutting through a mountain which reaches an elevation of 14,500 feet.

The mines were extensively worked some time ago to a depth of several hundred feet, with small success. During the last fifteen years, however, they have produced a value of over £9,000,000, of which about £3,000,000 has been paid in dividends. Until recently they were worked on Spanish-American lines, but during the last two years a large modern hoisting-and-drilling plant has been erected.

They are worked through a tunnel, which cuts the veins at 1,500 feet from its mouth. This has been extended through the mountain towards the reduction works, $4\frac{1}{2}$ miles away, the remaining distance consisting of a gravity-road.

The lowest depth attained (1891) was 1,190 feet below the level of the main tunnel. During 1891 5,942,000 ounces of silver were produced, yielding a net profit of over £420,000. 17,193 tons of ore, containing 4,041,000 ounces silver were exported to Europe, and 13,890 tons, containing 1,894,800 ounces, treated locally. The cost of mining, handling, and sorting is about £5 15s., and that of milling £4 19s. per ton.

The gangue is quartzose, carrying iron and copper pyrites, galena, blende, and tetrahedrite. The latter carries most of the silver; it is usually massive, but sometimes beautifully crystallized.

The following is an average analysis of sorted ores:—

Silica...	...	...	...	...	23·00
Copper	...	...	...	...	1·89
Lead ...	...	...	...	...	11·30
Zinc ...	...	...	...	...	21·50
Iron ...	...	...	...	...	11·60
Sulphur	...	...	...	...	26·00
Arsenic	...	...	...	...	0·35
Antimony	...	...	...	...	1·80
Silver	...	from 120 to 300 ounces per ton.			

The ore is pulverized in Gruson (ball) mills of German make, each mill grinding 10 to 12 tons per 24 hours to 50 mesh, 130 lbs. being crushed per horse-power per hour.

The ore is roasted in reverberatory furnaces with 4 per cent. of salt, 25 lbs. of brushwood being required per 100 lbs. of ore. After withdrawal from the furnace, the ore is spread out on the cooling-floors to prevent farther chlorination.

The total losses average:—

	Per Cent.
In transportation and grinding ...	1½ to 2
In roasting ...	3 „ 5
In amalgamation ...	8 „ 10
In stolen amalgam	0·1
In melting into bars	0·6

The net extraction thus varies from 82 to 87 per cent., the silver averaging 994 fine.

New reduction-works are being built near the coast, and the low-grade ore—of which there is 60,000 to 70,000 tons, of 75 to 90 ounces per ton, in the dump alone—will in future be treated there, 395 miles away from the mine. G. E. C.

PHOSPHATES IN CANADA.

The Phosphate Deposits of the Ottawa District. By R. W. ELLS. *Canadian Mining and Mechanical Review*, 1893, vol. xii., pages 39-40.

The deposits are of two kinds, the apatite, occurring in Laurentian rocks, and the phosphatic nodules, found in fossiliferous strata of Cambrian and Cambro-Silurian age. The latter have not been worked.

Apatite was first mined in Ontario some thirty years ago, but up to 1875 the production averaged only about 1,000 tons per annum. From 1878 to 1889 it was but little more—the output for these twelve years being only 16,000 tons. In Quebec, on the other hand, where mining commenced in 1871, a production was reached in 1885 of 28,535 tons.

It occurs in two ways—either in association with intrusive masses or dykes of pyroxene, cutting through the altered Laurentian gneisses, or as crystals, often of large size, disseminated through limestone. The more economically important deposits belong to the former class, the apatite being nearly always found in more or less connected pockets near the contact with the gneiss.

The origin of the deposits is briefly discussed—the conclusion being that they were formed by the action, on the calcite of the pyroxene masses, of vapours charged with phosphoric acid ascending along the line of contact, and impregnating the softened or heated mass in patches near the contact.

G. E. C.

PHOSPHATES IN FLORIDA, UNITED STATES.

- (1) *The Phosphate Industry of Florida.* By FLOYD B. WILSON. *Engineering Magazine (New York)*, vol. iv., pages 80-94.

The phosphates of Florida may be divided into four classes—Peace river pebble, land pebble, hard rock, and mixed land pebble and plate rock. The Peace river pebble is pumped up from the river-bed, and, after drying, is ready for shipment. It is of about 60 per cent., and finds a ready market. The first discovery of these beds was made in 1889, and it is said by some that they are nearly worked out.

The land pebble is often of very high grade, but no great quantity has yet been shipped, difficulty being found in washing out the clay in which it is embedded.

The hard rock phosphate occurs in pockets of very varying size, there being usually an overburden of 10 or 15 feet above the beds. To remove impurities it has to be crushed, washed, and dried before shipment.

The mixed land pebble and plate rock is of very high grade, averaging from 77 to 79 per cent., and occurs in potholes on the jagged surface of waterworn Eocene limestone. These potholes are filled with small pebble and broken plate, and are sometimes as deep as 40 feet. There is a sand overburden varying from a few inches up to 3 feet in depth. The deposits extend only over an area of $2\frac{1}{2}$ by $1\frac{1}{2}$ miles. The phosphate is mixed with clay and sand, which are washed out, and it is then dried—the whole process being automatic.

G. E. C.

- (2) *Suggestions as to the Origin and Deposition of Florida Phosphates.* By WALTER B. M. DAVIDSON. *The Engineering and Mining Journal (New York)*, 1891, vol. li., pages 628-629.

The phosphate field in Florida includes nearly the entire western half of the peninsula. The phosphates are divided by the author into—(a) hard rock or boulder phosphate; (b) soft rock; (c) nodular phosphate; (d) river pebble phosphate; (e) land pebble phosphate.

Until a few years ago, when Mr. Albertus Vogt and Colonel John Dunn found that there was phosphate in Florida, the whole peninsula was looked upon as a coral reef covered with a blanket of sand.

Now the interest is so universal and so much capital is at stake that the United States Geological Survey have ordered a reconnaissance; indeed, they are at present in the field, and their results will be looked forward to with interest.

Geologists here have a hard task, for there are practically no outcrops, no sections to be studied, no synclinals or anticlinals to be measured, and nearly the whole peninsula is covered with a mantle of sand. Many artesian wells have been sunk, the most valuable to geologists being that sunk at Lake Worth, on which Mr. N. H. Darton, U. S. Geological Survey, has published a monograph recently.

The author maintains positively, from his personal observations, that an Eocene or Miocene limestone underlies the greater part of Florida and, broadly speaking, the entire phosphate field. Referring to the wave or beach theory, advanced by Dr. Wyant,* the author considers it very ingenious and distinctly scientific, and says that while, no doubt, wave action came into play, it does not explain satisfactorily the rock phosphate deposit in all its vagaries.

Apparently, during the close of the Cretaceous period the shores of the Gulf of Mexico were elevated by gradual upheaval until they formed shallow lagoons, estuaries, and bays. In these shallow, warm seas lived myriads of shell-fish, many secreting phosphate as well as carbonate of lime, as is shown by the analysis of a shell of *Lingula ovalis*, quoted by Dr. Dana, as containing 86 per cent. of phosphate of lime. Fishes of all kinds abounded in these waters, died, and their bones, while mostly disappearing, served to increase the amount of phosphate of lime in the limestone.

Gradually the shores emerged from the seas, and while they rose came the glacial epoch. The cold of this epoch drove all living creatures which could travel southward. The result was that the great mammal horde flocked to the swamps and estuaries of Florida, where they died.

During the risings and sinkings of Florida, the author maintains that leaching by water caused denudation and solution of the highly phosphatic limestone, bicarbonate of lime being carried away in solution and phosphate both in solution and suspension. In the stiller waters of the estuaries, etc., the phosphate of lime in suspension was deposited as an alluvial secondary deposit. At certain places, the water in the streams and rivers, apparently, gave up the phosphate in solution, phosphoric being replaced by carbonic acid. The result is evidently the irregular deposits of rock, boulder, or high grade phosphate of lime.

The great similarity between the appearance of the hæmatites of Virginia and the hard rock phosphates of Florida was first pointed out by Mr. N. H. Darton, and the identity is very striking.

The phosphate carried in suspension, etc., was deposited in the back waters of the rivers and in the shallow streams, forming the soft rock or phosphate. With this were the bones of the beasts mentioned above. "Then, in some not understood way, segregation and accretion took place, the richer phosphatic nodules attracting to themselves the phosphate within the radius of their attraction, and thus was formed the 'nodular' phosphate rock, which consists of rich concretionary nodules in a poorer calcareous matrix mixed with bones and teeth. There is no dispute as to the immediate origin of the pebble phosphate, river and land. The nodules and the bones, mostly rounded by attrition, were washed down by the rivers and distributed in their ever-changing beds with sand and mud. The nodules and the bones form the gravel in the banks in the river beds, the 'river pebble' being merely the present result of river action."

J. W.

* *Engineering and Mining Journal* (New York), August 23, 1890.

NAPHTHA IN AUSTRIAN GALICIA.

Die Naphtafelder in Wietrzno. By CLAUDIUS ANGERMANN. Jahrbuch der k. k. Geologischen Reichsanstalt, 1889, vol. xxix., pages 281-288, with six sections and one map in the text.

The naphtha occurs in crevices in Eocene sandstones, which lie in an anticlinal beneath the bituminous "menillite shales." The sandstones were fractured when the folding of the strata took place, whilst the more flexible shales were bent but not broken.

The Wietrzno naphtha works are situated at a height of about 980 feet above sea-level, and the gas wells go down to 822 feet, so that the actual height of the natural gas reservoirs above sea-level is about 164 feet. The pressure of the gas at bank is 2 to 3 atmospheres, while at the bottom of the shaft it attains 15 atmospheres.

The author shows that the lie of the beds is such that the gas-bearing deposits cannot extend very far to east, north, or south of the present workings; to the west are the older well-known works of Bobrka. Some shafts were put down by unscientific searchers at points where the beds are too steeply inclined to permit of the gas-bearing sandstones being reached, and in this way a sum of £17,000 was lost.

O. S. E.

PETROLEUM IN FRANCE.

Découverte de Terrains Pétrolifères dans la Limagne d'Auvergne. By P. DUBREUIL and J. DE CLERCY. Génie Civil, 1892, vol. xxii., page 102.

Mr. J. de Clercy concluded that mineral oil would probably be found at a considerable depth in the Limagne d'Auvergne, from the similarity of the geological formations to those on the eastern side of the Vosges, and the Tertiary formations of Galicia. He began to bore on the Fauvel system in September, 1891, near Pont du Château station. This hole went down 720 feet and cut some fissures containing bitumen without reaching the oil-bearing strata.

A second boring was made on the opposite side of the plain at Pont Battu near Biom. This hole reached a depth of 906 feet, and proved the existence of beds of shale impregnated with carburetted gases, light petroleum oils and various oily minerals, a certain sign of the vicinity of free petroleum. This hole passed first through limestone impregnated with viscous bitumen. At 294 feet a bituminous crevice was cut which yielded abundance of bitumen of a lighter and more oily nature. At 333 feet the strata at the bottom pushed up, and filled the hole for 30 feet, the flow of bitumen increased, and the first liberation of inflammable gas was observed. From that time progress was impeded by continual upheavals accompanied by gas. At 636 feet the hole was filled with calciferous sand for more than 300 feet, gas could be constantly lighted at the top, and the bitumen became very light and fluid. Other upheavals of 180 and 240 feet occurred, and the hole was then tubed to a depth of 573 feet. At 645 feet a new outburst filled the hole for 426 feet, and the supply of light bitumen and gas was abundant; from 654 to 870 feet hard limestone was passed through without bitumen or gas, but the water coming out of the hole had a strong smell of petroleum different from the smell of bitumen. This water contained little oil, and was very salt. A series of very hard argillaceous beds were next found, with thin beds of siliceous sand, and at 900 feet there were fresh outbursts both at the bottom and 639 feet down, which stopped the boring.

The hole was cleaned out again, during which operation much oil and gas was given off with the water. The bottom again burst up and the boring was stopped on November 1st, 1892, until stronger mechanical appliances could be erected.

It is concluded that petroleum exists under considerable pressure, which may produce spouting wells, if deeper holes encounter permeable measures. W. N. A.

GEOLOGY OF THE CAUCASIAN (BAKU) NAPHTHA REGION.

Preliminära meddelanden från de kaukasiska naftafälten. By HJ. SJÖGREN. Geologiska Föreningens, Förhandlingar, Stockholm, 1891, vol. xiii., pages 89-110, 223-255, with sketches in the text and a coloured map.

The author classifies the strata as follows :—

Local Name.	General Name.	Geological Age.
6.	Caspian	Alluvial
5.	Aralo-Caspian	Diluvial
4. Baku series	Pontino-Caspian	Pliocene
3. Apscheron series		Miocene or
2. Balachany series	... ..	Oligocene
1. Sumgait series	... ..	Eocene

1. The Sumgait series includes shales, sandstones, and reddish-brown ferruginous marls. The occurrence of iron ochre, nodules of pyrites, abundant rock-salt, and gypsum, the last named often in enormous masses, is noticed. In the Mahannä district, in conjunction with the anticlinal folding of the rocks, there are mud volcanoes with outflows of naphtha and natural asphalt. Limestone also appears in this district and is, moreover, the characteristic rock of the Beschbarmak massif.

2. The Balachany series is the naphtha-bearing series *par excellence*. It comprises grey to greyish-brown slaty marls, calcareous sandstones, and loose sand-beds, saturated with naphtha or water. Fragments of lignite occur, and carbonaceous plant-remains are found abundantly in a hard grey horizontally-bedded sandstone. In the loose sands, the presence of rounded masses of sandstone, about the size of a man's head or larger, is often noticed. It is presumed that these represent really the *débris* of the calcareous sandstones, whose matrix has been dissolved away by the carbonic acid evolved from the naphtha. These masses are found to be a great obstacle in boring for naphtha. Nodules of pyrites occur throughout the series.

3. The Apscheron series, which in some places is conformable with, in others lies unconformably upon, the Balachany beds, is partly argillaceous and partly calcareous in character. It contains limestones which are exclusively built up of molluscan shells.

4. Upon the Apscheron beds rests unconformably the Baku series, made up of shelly limestones, alternating with marls and sands. Above these come the limestones, sands, and gravels of the Aralo-Caspian series.

O. S. E.

THE PETROLEUM INDUSTRY OF BAKU.

État actuel de l'Industrie du Naphte dans la Presqu'île d'Apschéron. By A. LEPROUX. Annales des Mines, 1892, series 9, vol. ii., pages 117-162, and 7 figures.

The subject is considered under four heads—(1) History of the development of Baku to the present time. (2) Conditions and methods of working. (3) Treatment of the petroleum, employment of the residuals (*mazout*) for the manufacture of lubricating oils, and for heating steam-boilers. (4) Cost of production, transport, taxes, etc. Commercial position of Baku.

1. *Historical*.—About the year 1800 the production of petroleum from Baku varied from 1,500 to 2,000 tons. Baku was definitively annexed to Russia in 1801,

and a monopoly established by the Government. Under this *régime*, which lasted until 1872, the production of petroleum increased slowly but continuously, attaining 25,000 tons in 1872. The suppression of the monopoly and gradual abolition of the taxes caused the production to increase to 333,000 tons in 1878.

Inconveniences arising from over-production and want of means of transport began to be felt about that time. In 1884, the railway from Baku to Tiflis was opened, and the production increased rapidly, exceeding 2,000,000 tons in 1887, and 3,000,000 tons in 1888, in spite of the re-establishment of high taxes.

At the present time, the production is not increasing, but not from exhaustion of the supply. In twenty years the production has become equal to that of Pennsylvania, but the value of the petroleum from the two countries is not the same. The Pennsylvanian petroleum furnishes 70 to 80 per cent. of burning oil, that of Baku only 30 per cent.

The oil-lands may be classified as to ownership as follows:—

1. Lands bought from the State, or granted to individuals, who either retain them, or have let or sold them.
2. Lands belonging to certain villages, communities, etc., rented by agreement for development.
3. Lands belonging to the State, of which a very small portion is leased.

Only about one-half of the oil-lands is available for working, but the production is so active that their exhaustion must only be a question of a few years. There will then remain for development the lands retained by the State, without counting the numerous deposits of the rest of the Caucasus, Turkestan, and Bokhara, which, however, produce less remunerative petroleum.

2. *Working*.—The geological formation consists of two series of Tertiary beds, the lower of which yield the petroleum. The upper series is composed of hard limestones and shales and reaches a thickness exceeding 2,000 feet in some places. The lower, or petroliferous, series is composed of sandstone, argillaceous sandstone, sand and shale, the total thickness of which is unknown, but has been proved to be 2,300 feet near Balakhany and Binagadine.

The difficulties of extraction are caused more by the looseness of the strata than their hardness. The boreholes are continually obstructed by running sand, of which the spouting wells throw up large quantities, and the employment of torpedoes to renew the supply is impracticable.

The choice of position for a well is not guided by any precise or logical considerations. It is not known why some pits yield much more abundantly than others. Of two pits only some yards apart, one may yield thousands of tons per day, and the other hardly enough to pay costs.

The spouting of the oil is supposed to be entirely due to the pressure of gas dissolved in the petroleum, and is supposed to occur when a sort of bell-shaped cavity is formed above the base of the pit tubing, an occurrence altogether local and purely accidental, and impossible to foresee before a site of a well is chosen.

It is only known that the abundance of oil increases with the depth, that it is greatest where the bed is pinched or compressed, that it is generally small where the beds are fissured, and that it is very irregular.

The wells are bored, generally with rods; the American system of boring with ropes has been tried, but was not successful. The diameter of the holes varies from 17 to 24 inches, generally beginning with the latter diameter which is gradually reduced as the hole descends; the holes are tubed throughout. The boring is carried as deep as possible, but rarely beyond 1,000 feet. The cost of a complete installation with a well 800 feet deep is about £3,160, including the redemption of capital. The rate of boring is about 6 feet per 24 hours, with an engine of 10 horse-power.

When a spouting well is produced, a violent outburst of gas takes place, soon followed by petroleum mixed with sand. The pressure of the gas sometimes reaches 20 atmospheres, and there have been cases where not only were the boring-tools blown out of the holes, but even the column of tubes has been raised, and bent by the gases, in some cases leading to the complete loss of the boring. On account of these considerable pressures, the contrivances used in Pennsylvania for collecting the oil are rarely used, and much of the petroleum from spouting wells is lost, if large reservoirs have not been previously prepared. A spouting well, instead of being a source of riches, is sometimes the cause of ruin because of the enormous havoc produced by such a violent inundation. When the boring is stopped before spouting occurs the oil is raised in cylindrical vessels with a valve at the bottom by means of a small steel-rope. It is necessary to clean the hole occasionally from obstruction by sand.

The cost of this extraction (labour and engine-power) is from 12s. 6d. to 16s. a day. Extraction continues so long as the output is sufficient to pay costs, which depends on the productiveness of the hole, and the price of crude petroleum. At present an output of 6 or 7 tons per 24 hours justifies continuance of work.

The richness of the holes varies from absolute sterility to the spouting out of millions of gallons per day. The cost of production therefore varies infinitely. The average production of all the wells at Balakhany may be said to have averaged for some years 50 tons per 24 hours.

3. *Treatment of Petroleum and use of Residuals.*—All the crude petroleum is treated at Baku, in the vast suburb called Ville-Noire, where there are more than 150 factories, some of which (Messrs. Nobel's in particular) are very large.

The oil is conveyed from the wells either in pipe-lines or boats for distances varying from 5 to 7½ miles. A pipe-line installation comprises a pumping-station and reservoirs at each end of the line. Worthington or analogous pumps are employed to pump the oil through the pipe-lines. The reservoirs are of thin rivetted sheet-iron, costing about from 10½d. to 12½d. per cwt. of oil contained. The pipes are of wrought-iron (cast-iron offering much greater resistance to the oil-flow especially in winter). An installation to pump 800 tons in 24 hours 6½ miles, with a difference of level of 197 feet in favour of the flow cost £12,666.

The selling price of crude petroleum varies enormously, or from 2s. 4½d. to 12s. 8d. per ton.

The treatment comprises the manufacture of lighting-oil and lubricating-oils, by fractional distillation preceded and followed by purifying operations. Lubricating-oils are made from the residuals after the lighting-oil is extracted, but the major part of such residuals is used for heating purposes.

The processes of manufacture, testing, barreling, etc., are briefly described.

The bulk of the residuals (*mazout*) from the manufacture of lighting-oils as well as that from reservoirs where the crude petroleum has stood so long that the oil has evaporated is used for heating purposes. It is used in all the steamboats on the Caspian Sea, the Volga and its affluents, on all the railways of the south-east of Russia, and in all the factories where it can be obtained, and its use for these purposes constantly increases. It produces no cinders, is easy to apply, and for equal weight more advantageous than coal. The theoretical evaporative power of *mazout* is 16·2 (1 pound evaporates 16·2 pounds), while that of anthracite is 12·2, and consequently an equal weight of *mazout* would theoretically evaporate 33 per cent. more water than anthracite, but while coal only yields 60 per cent. of its theoretical calorific power *mazout* may yield 80 per cent., making an advantage in its favour of 75 per cent. Consequently, whenever *mazout* can be had at a price below 7/4ths that of coal, it is advantageous to use it. It is so easily applied that one man can attend to 6, 8, or 10 boilers fired with it.

The results of trials in stationary boilers in Moscow are given, and a *résumé* of three articles published in 1884, 1889, and 1890 in the *Proceedings* of the Institute of Mechanical Engineers on the use of *mazout* in locomotive engines.

4. *Cost of Production, Transport, Imports, etc. Commercial Situation of Baku.*—As has been stated, it is not possible to fix the cost of production of crude petroleum, but its selling price varies from 2s. 7d. to 12s. 11d. per ton.

The cost of production of kerosene from crude petroleum at the former price is approximately 9s. per ton. The cost of production of *mazout* is very variable; in the summer of 1891 it was 6s. 4d. per ton.

The lighting and lubricating-oils only are exported in quantity, and nearly all the *mazout* is consumed in Russia. The oils are carried in tank-ships holding 700 to 800 tons, or in cistern-waggons holding 10 or 12½ tons each. Kerosene costing 9s. per ton at Baku is worth 39s. 6d. per ton at Batoum, and *mazout* costing 6s. 4d. per ton at Baku is worth 32s. per ton at Batoum.

The commercial situation at Baku in 1891 was very unfavourable, and more than 70 factories were closed during that year. In Russia, Russian petroleum can hold its own, owing to protective duties, but abroad it cannot compete favourably with American oils, and the industrial conditions at Baku are adverse to its success in the struggle.

The methods of working are imperfect, the petroleum is badly collected, much being lost by drainage and evaporation. The processes of distillation and refining compare unfavourably with American methods, and Russian petroleum only yields 30 to 40 per cent. of kerosene, of which some American petroleum yields 80 per cent.

The geographical situation of Baku is also unfavourable for exportation to Europe: the increasing Russian demands, however, may suffice for its future profitable working.

W. N. A.

NAPHTHA IN THE CAUCASUS.

Ueber Naphtha im Kaukasus. ANON. *Berg-und Huettenmännische Zeitung*, 1892, vol. li., pages 287-289.

The probability of the early exhaustion of the naphtha-wells of the Caucasus, predicted by many Russian engineers, is denied by the well-known chemist, Prof. Mendelejew. Comparatively few wells are at work in the present oil-district, and these of shallow depth, and, in addition, new oil-finds continue to be made farther away. While the American wells are about 25,000 in number, and reach depths of 1,600 feet, not more than a few hundreds are at work in the Caucasus, and their depths do not exceed 700 feet. In general, the boreholes yield about 16 tons per day each, and those that yield less than 4 or 5 tons are abandoned.

The whole naphtha district has an area of about 6½ square miles. It is bounded on the south and east by the chalk beds of the Aral-Caspian valley, down under which the naphtha-bearing strata extend. Chalk beds have originally formed a sort of roof over the strata of sandy shale containing the naphtha, and the erosion of a part of this roof by the sea has rendered the underlying strata accessible. To the westward, the district extends as far as the mud-volcano of Bog-boga. To the north, the shale beds crop out in a line extending through the valley of Balachani and the southern shore of Lake Sabratski.

The naphtha-bearing strata consist of coarse and fine sands alternating with slaty, variegated shale, and lie in a gentle slope from south-east to north-west.

About 4,000,000 tons of naphtha a year are produced in the Caucasus, 500,000 tons of this being sent abroad, and a considerable quantity being used on the spot. More than 1,500,000 tons of waste oil remain in the Caucasus, and this, which in other countries would form a considerable source of profit, is in Russia simply thrown away. It is given away gratis for use as fuel on the steamers of the river Volga and Caspian Sea, and in various engineering works in the neighbourhood.

The petroleum distilled from the naphtha is sent inland by the Volga river and by the Trans-Caspian railway.

In Baku, naphtha costs 0·015d., 0·020d., or at the most 0·025d. per lb., and its price in various parts of Russia depends chiefly on the cost of its carriage from there.

In Moscow, it costs 0·25d., 0·28d., and as much as 0·30d. per lb., against 0·30d. per lb. of coal. The Russian tariffs for the carriage of coal are very high, and naphtha will continue to supplant it as a fuel unless the Government takes the matter up.

The amount of naphtha now raised in the world is about $\frac{1}{5}$ th of the whole output of coal, and although new sources of supply have been discovered in the Trans-Caspian and other districts, it is not likely that the yield will become considerable enough for it to take the place of the older fuel.

A. R. L.

PETROLEUM IN INDIA.

- (1) *Preliminary Report on the Oil Locality near Moghal Kot, in the Sherani Country, Suleiman Hills.* By R. D. OLDHAM. *Records of the Geological Survey of India*, 1891, vol. xxiv., pages 83-84.

The oil issues from a hard, unfossiliferous sandstone, 600 feet thick, and probably of Cretaceous age. The oil is most abundant near the base, where the rock is porous. The springs are found in the river-bed, and they appear to have been flowing for many years. The oil is of a pale yellow colour, clear, and free from water. Analyses prove that the oil is of high quality. The actual flow of oil at present is 10 gallons per day.

- (2) *Report on the Oil Springs at Moghal Kot in the Shirani Hills.* By TOM D. LA TOUCHE. *Records of the Geological Survey of India*, 1892, vol. xxv., pages 171-175, and two plates.

These oil springs occur near the village of Moghal Kot in the Sherani Hills. They have previously been reported on, and samples of the oil have been analysed, but the present exploration was made to ascertain whether the oil could be procured in sufficient quantities to render it commercially valuable. The oil springs are found in a deep, narrow gorge, cut by the river Toi through a ridge of hard, fine-grained quartzose sandstone, overlain by massive limestone. The oil issues close to the water's edge, and most copiously near the base of the quartzose sandstone. The points of outflow seem to be determined by the existence of beds of shale intercalated in the sandstone. On issuing from the rock the oil is limpid, slightly yellow, and opalescent. From a rough calculation, it appears that one hole would yield a gallon of oil in $4\frac{1}{2}$ hours, while another would take 14 hours.

Although the ridge of rock yielding the oil extends for 30 miles to the north of the river, the occurrence of the oil itself seems restricted to this spot. The peculiar structure of the rocks in the gorge above Moghal Kot facilitates the escape of oil where the springs occur.

The practical conclusion arrived at by the author appears to be that the present flow of oil might, by suitable borings, be sufficiently increased to make it commercially valuable.

- (3) *On Mineral Oil from the Sulciman Hills.* By THOMAS H. HOLLAND. *Records of the Geological Survey of India*, 1891, vol. xxiv., pages 84-97.

This paper records an analysis of Mr. Oldham's samples (see previous paper), which are inferior to those previously analysed. The paper also contains a valuable bibliography of the petroleum resources of the Punjab and Baluchistan areas.

- (4) *Second Note on Mineral Oil from the Sulciman Hills.* By THOMAS H. HOLLAND. *Records of the Geological Survey of India*, 1892, vol. xxv., pages 175-180.

Analyses of two samples of the oil from Moghal Kot collected by the previous writer are as follows:—

Specimen A was a deep yellow, mobile liquid, slightly turbid. The specific gravity, at 60 degs. Fahr., was 0.819. The flashing-point (Abel test) was 75 degs. Fahr. The crude oil contains 87½ per cent. of illuminating oil.

Specimen B is a clear, rich straw-coloured liquid. The specific gravity, at 60 degs. Fahr., is 0.811. The flashing-point is 64 degs. Fahr. The crude oil contains 84 per cent. of illuminating oil. There would be a slightly greater waste in preparing oil B for the market. Both samples are of very high value, so that, if occurring in sufficient quantity, no foreign oil could compete with it.

G. W. B.

PETROLEUM IN PERSIA.

- Note sur les Gîtes de Naphte de Kend-é-Chirin.* By J. DE MORGAN. *Annales des Mines*, 1892, series 9, vol. i., pages 227-238, with sections in the text.

The author sketches briefly the physiography of the hilly country between Hamadan and Zohab, a district which forms part of the system of parallel ranges whose height drops gradually from the summit-level of 7,000 feet at the Zagha Pass to 150 feet at Bagdad, in the plains of Mesopotamia. Hamadan lies within a zone of igneous rocks; west of this, fossiliferous Jurassic strata were observed, overlain (apparently in regular succession) by Cretaceous rocks, Nummulitic limestones, and a great series of later Tertiaries with naphtha-bearing beds. The naphtha zone forms a long band, running north-west and south-east from Kerkuk (in Turkish territory) to Kasrashirin, near Shahku. The existence of prolongations of the band north and south of these localities is not improbable.

However that may be, the author's attention was specially devoted to the deposits of Kandashirin, situated at a height of about 1,560 feet above sea-level in the central portion of the naphtha zone, and distant about 95 miles from Bagdad. The immediately surrounding country is rather flat, but there are a few low hills of soft Tertiary rocks. The naphtha occurs here in an anticlinal of unfossiliferous post-Eocene sands and marls, so far as it has at present been tapped; but the author shows good reason for the hypothesis that the main reservoir really lies in one of the synclinals north and south of the anticlinal fold.

At Kandashirin, a little river cuts through the crest of one of the anticlinal folds, so exposing the petroliferous marls beneath. These beds incline to the right and the left of the crest, which runs west 12 degs. north, and their dip varies from 75 degs. at the line of fracture to 18 degs. at a distance of 5,000 feet (1,500 metres); farther on the beds become horizontal, and afterwards rise again. Excepting where exposed by the stream, the marly beds containing the petroleum are entirely covered by superior strata, certainly more than 8,000 feet (2,500 metres) in thickness, and devoid of fossils. The uppermost marly bed contains strings of ozokerite,

varying in width from 0.10 inch (2 or 3 millimetres) to $\frac{1}{4}$ or $\frac{3}{4}$ inch (15 or 20 millimetres), which have been produced by the infiltration of the mineral oils into the fissures of the marl; these the author considers to be of no practical value.

Numerous remains of shallow wells are visible, and the Kurds have cut a deep trench and sunk two wells, each of about 30 feet (9 metres) in depth. These fill up with salt-water and naphtha, and are emptied every four or five days by means of a cord and bucket, each operation yielding about 50 gallons (250 litres) of crude oil and a large amount of brine—the latter being evaporated down to impure salt, with a strong odour of petroleum, which sells in the country at about $\frac{1}{4}$ d. per pound.

The crude oil is taken on mule-back some 10 miles to the village of Kasra-shirin. It is very fluid, green, has a strong odour, and sells crude at about 1d. per pint ($1\frac{1}{4}$ d. per litre). It is then refined, when it fetches about double.

The salt produced from the brine in the evaporating-cabins is very bad and strongly tainted with petroleum. In short, the methods of working are of the most primitive description, and only 10 to 12 men are employed. The Kurdish wells have only touched the surface of the deposit; they do not, therefore, go down to the impermeable strata which form the bed of the subterranean naphtha-lake.

The author, in conclusion, points out that the petroleum from Baku and from far Pennsylvania, which now monopolizes the markets of China, India, Persia, and Turkey, may at some future date be displaced by the petroleum from the above-described deposits, the shipping port for which would be Bagdad.

G. E. C. & O. S. E.

SAFETY-CATCH FOR PUMP SPEARS.

Fangcorrichtung für Pumpengestänge. By J. SPRENGER. *Berg- und Hüttenmännische Zeitung*, 1888, vol. xlvii., pages 205-207, 223-226, and 231-235, and two plates.

In order to reduce the damage done by falling pump-spears in case of their breaking, it has been the practice in some pits to fit catches at intervals in their length in the shaft. The fall then depends on the vertical distance apart of the catches, these having to be the stronger and heavier the wider the intervals. In the König mine, near Neunkirchen, a method is employed by which the broken spears are caught before they have gathered momentum, and the engine brought to a stand at once, and for this system the fittings are lighter and less clumsy than those usually adopted.

There is an upper length of 220 feet of wooden spears, and a lower length of 260 feet of iron ones; and there are clutches fitted at about 60 feet from the upper end and 50 feet from the lower end. To each side of the spear at each of these places is a spindle with eccentric wheels at its ends, in the perimeters of which are deep grooves corresponding in shape to the edges of an iron standard fixed between them opposite the centre of the spear. Between the two systems of wheels is a strong rope; from the upper system to the top, another of about half the strength; and from the lower system to a cleat near the bottom of the lower spear is a third rope of about a quarter of the strength of that first mentioned.

The attachment of the ropes is similar in the two systems. Each spindle has a short crank which is turned inwards and attached to the obtuse side-angles of a loose parallelogram made of four iron bars, the ropes being attached above and below to its acute angles.

Close to the top of the shaft the rope is reeved through two eyes on a plate fixed to the spear. A nut between the two keeps the rope taut below, and in cas

of a breakdown will fly up against the upper one, there being a few inches of play between. The ropes are made taut by tightening screws, and so arranged that the cranks on the spindles point inwards and keep the eccentric wheels with their smaller diameters towards the fixed standards between them. The upper rope is carried first over the end of the pumping beam and then inwards over a pulley, and at its end hangs a heavy weight which, in case of accident, will fall on a lever and shut off the steam. In case a spear breaks the weak lower rope will break also, and this setting free the parallelogram, the lower eccentric wheels are turned by their own weight till they grip the fixed standard and thus arrest the falling spear. Meanwhile the upstroke continuing, the next weakest upper rope will give way and allow the weight to fall and shut off the steam. The strong middle rope does not break, but being kept in considerable tension before the accident will, by returning to its original length, help to bring both upper and lower eccentric wheels into position to grip the standards. The standards, about 10 feet long, are fixed at their upper and lower ends on to beams lying across the shaft.

For deeper pits more than two clutches may be required, and these can be arranged in a similar manner. In the König mine the arrangement was practically tested, by cutting first the lower rope and then the upper one, while the pump was at work. The spears were at once arrested, and the engine brought to a standstill.

A. R. L.

BURMAH RUBY MINES.

Note on the reported Namsêka Ruby-mine in the Mainglôn State. By FRITZ NOETLING. Records of the Geological Survey of India, 1891, vol. xxiv., pages 119-125.

The original matrix of the ruby is a crystalline limestone, but the mine is worked in river alluvium. Valuable rubies are said to have been found at this mine, but a trial of three days of eight hours each, with twelve coolies, produced no result. Since any rubies which may have been found in this mine have probably been washed down from the ruby-mine district by the river Mogaung, other deposits might be expected along the course of this stream.

G. W. B.

EXPERIMENTS WITH SAFETY-LAMPS.

Expériences sur les Lampes de Sécurité. Rapport présenté à la Commission du Grison au nom de la Sous-commission chargée des recherches expérimentales. Annales des Mines, 1892, series 9, vol. i., pages 47-66, and plates III. and IV.

The experiments were made by Messrs. Mallard, Le Chatelier, and Chesneau at the École des Mines, in a laboratory fitted up for the purpose. No attempt is made to compare the inconveniences or advantages of the lamps tried except as to safety and lighting power.

I. DESCRIPTION OF THE APPARATUS.

One apparatus was used for examining the behaviour of safety-lamps when placed in a stationary or slowly-moving explosive mixture of air and marsh gas. The formene was stored in a gasometer of 212 cubic feet capacity, from thence it passed to a meter. A fan worked by a gas engine at the same time passed air through another meter. The mixed gas and air passed by a pipe into the base of a square box in which the lamp was placed. This box was glazed on four sides for observation, and

fitted with a small chimney at the top. Regulating cocks allowed the flow of gas and air through the meters to be adjusted. By another pipe and cock, lighting gas could be substituted for formene. In this apparatus a safety-lamp could be kept for several hours in a known mixture of air and formene or air and lighting gas.

The second apparatus was used for testing lamps in mixtures of air and lighting gas moving at great velocities. The lighting gas passed through an 800-burner meter, into the base of an upright pipe into which air was also forced by a fan. The mixed gas and air ascended the vertical pipe and passed into a short horizontal box in which the lamps were suspended opposite a window for observation. This box was movable on a horizontal pivot fixed at its junction with the vertical pipe, so that it could be moved or jerked by a cord passing over a pulley to the observer. The velocity of the explosive mixture was measured by an anemometer. The proportion of gas was measured by the meter. The composition of the mixture was usually the most explosive possible. The velocity could be raised to 20 or 23 feet per second, corresponding to 33 or 40 feet in the area occupied and restricted by the lamp.

II. RESULT OF THE EXPERIMENTS.

Modified Boty Lamp.—A modification of the Boty lamp, having the gauze cylinder replaced by a cylinder composed of flat iron rings placed one above another and maintained 0.039 inch apart. Its weight, without oil, was 2.96 lbs. The inventor hoped that the large surface of the flat rings between which the air enters and leaves the lamp would so cool enflamed gas as to prevent the passage of flame even in currents of high velocity. When placed in a mixture of maximum explosiveness the wick-flame was extinguished, but the gas continued to burn in the interior of the ringed cylinder which became red-hot. With a velocity of 8.03 feet per second, (12.13 feet at the lamp) explosion did not occur at the end of 10 minutes; with higher velocities the results were different, as follows:—With a velocity of 10.66 feet per second (15.41 feet at lamp) explosion in 30 seconds; with a velocity of 19.18 feet per second (27.88 feet at lamp) explosion in 5 seconds; with a velocity of 25.58 feet per second (34.27 feet at lamp) explosion instantly. The hope of the inventor was not realized, as it only required a slight increase of velocity to pass the flame.

Pieler Lamp.—This lamp has a double gauze and a shield with a longitudinal window for observation, closed by a movable shutter, and fed with alcohol. The weight when empty was 3.78 lbs. With a velocity of 8.03 feet per second (15.35 feet at lamp) the lamp with shield and 2 gauzes, the window open and directed towards the current, the interior gauze reddened strongly; but explosion was not produced at the end of 5 minutes (the lamp was violently agitated in all directions by sharp rotary movements of the box by the cord). With the same velocity, but the lamp with shield and 1 gauze only, the same result was obtained. Without the shield, but with 2 gauzes, explosion resulted in 15 seconds. With a higher velocity of 23.61 feet per second (45.10 feet at lamp), the lamp with shield and 2 gauzes, window turned towards current, lamp agitated in all directions, the gauzes reddened strongly, but no explosion after 5 minutes. Lamp with shield and 1 gauze same experiment repeated; no explosion occurred at the end of 5 minutes, but one happened at the moment when the gas was shut off,* flames produced by the combustion of alcohol vapour escaped with violence by the lower range of holes in the shield. These experiments show that the Pieler lamp, which is still regarded with

* Explosions produced at the very moment when the gas was shut off were observed rather frequently during the experiments. It may perhaps be explained thus:—The proportion of air being sharply increased the red-hot wires of the gauze enter into combustion and ignite the still inflammable gaseous mixture.

much suspicion, is safer than is generally supposed, and that the shield in this lamp is a great element of safety, even when it is pierced by a long but narrow window.

Cambeddes Lamp.—This lamp is specially designed to give a good light; it is constructed on the principle of an argand lamp, with an oil reservoir surrounding about $\frac{1}{4}$ of the glass, and its lighting power is about 1.25 candle-power.

The oil is kept at a constant level, and the lamp was devised to give more light than the ordinary type of lamp; that aim appears to be successfully fulfilled, as proved by the photometric experiments. The weight, when empty, is 3.33 lbs., and, with oil, 3.63 lbs. When placed in a mixture of air and marsh gas the wick-flame is extinguished and the gas does not burn in the interior. In a mixture of air and lighting-gas of maximum explosiveness moving at 9.67 feet per second (18.20 feet at lamp), in one experiment the lamp went out in a few seconds without lighting the gas inside; in two other experiments, after the extinction of the wick-flame the gas continued to burn inside, resulting in a heating of the lamp, which caused an abundant escape of oil from the reservoir; the experiments were stopped after 2 minutes. With a velocity of 18.36 feet per second (35.09 feet at lamp), exactly the same results were obtained.

The tests in presence of explosive gaseous mixtures showed that in a rapid current the flame is not passed outwards, but sometimes persists within the lamp, and thus causes oil to escape from the reservoir.

*Thorneburry Lamp.**—This is a petroleum lamp, the weight, empty, being 3.92 lbs. The petroleum used is relatively heavy, its specific gravity being 0.831 at 60 degs. Fahr., flashing (Abel test) at 256 degs. Fahr. The lamp is of excellent lighting-power, the maximum light after burning 15 minutes being 1.44 candle-power, and, after 40 minutes, 1.20 candle-power. The regulation of flame is delicate, depending on temperature. When the lamp is placed in a mixture of air and fire-damp, no cap is visible, on account of the light. The lengthening of the wick-flame gives very good indications, with 1.5 to 3.5 per cent. of fire-damp. With a greater proportion, the lamp smokes and the flame lengthens considerably. For these indications the flame must be first regulated in fresh air. In a current of air and lighting-gas at a velocity of 18.20 feet per second (36.40 feet at lamp), the lamp being in its normal state, the wick-flame extinguished at once, and the gas was not ignited inside. With the lamp without interior gauze, the wick-flame was extinguished, the gas burnt inside for 3 or 4 seconds, and then went out (two experiments). With the lamp without gauze, and the proportion of gas gradually increased to maximum, the flame lengthened progressively, smoked, but was not extinguished till 6 per cent. of gas was attained; with more than 6 per cent., the wick-flame was extinguished, and the gas burned inside the lamp for 2 or 3 seconds only; and the interior glass was broken, but not separated, when the lamp was kept 1 minute in the mixture of 6 per cent. This glass being thin, it might break and fall in pieces. The lamp was therefore tried without the interior glass, with a velocity of 21.97 feet per second (44.28 feet at lamp), the wick-flame was extinguished at once; the explosive mixture burnt in the gauze, which heated considerably; but there was no explosion at the end of 5 minutes. The lamp tried without gauze or interior glass gave immediate explosion.

The Thorneburry lamp possesses a high degree of security, and gives a very superior light. Till now, petroleum has not been considered a safe oil for safety-lamps. There is reason to consider whether there is serious danger when a heavy and not very volatile oil is used. Only an explosion in the oil-vessel is to be feared, which appears very unlikely with heavy oil.

* *Trans. Fed. Inst.*, vol. iii, page 236.

Fumat Lamp.—The latest modification of this lamp was used, in which the air enters through a series of holes in one side only of the lower part of a shield above the glass-cylinder, and the smoke escapes through the upper holes. The air passes into a sort of box, which hides half the glass, and after traversing the gauzes, reaches the flame. The lamp burns well in horizontal or descending currents, but not in ascending currents in the absence of gas. It gives a good light, equal to 0·87 candle-power. In a mixture of air and marsh-gas of maximum explosiveness, it is at once extinguished. With 6·5 per cent. of marsh-gas, it was only extinguished after 2 minutes. In a mixture of air and lighting-gas, at a velocity of 10·99 feet per second (37·39 feet at lamp), three experiments gave identical results; the wick-flame was extinguished at once, and the mixture burnt in the gauze from 10 to 20 seconds only, even with the holes in the shield facing the current. The Fumat lamp therefore possesses all the desirable guarantees of safety.

Marsaut Lamp.—After an accident in St. Etienne, in 1889, suspicion was cast on the Marsaut lamp, and it was proved that when placed in a mixture of air and lighting-gas, the gas continued to burn in the lamp after the extinction of the wick-flame, and fear was expressed that if the lamp so remained for long, the gauze might become so hot as to allow passage of flame, but Mr. Marsaut made experiments proving that the fear was groundless. In order to study this phenomenon, a large sheet of mica was inserted in the shield, so that the gauze could be seen. In a mixture of air and 10 per cent. of marsh-gas, introduced at the rate of 61 cubic inches per second, the wick-flame went out and the gas burnt within the gauze. The lamp was left in this condition several times for periods varying from 1 to 3 hours, and the gauze never sensibly reddened or altered; it was therefore proved that the imagined danger does not exist. In a current of air and lighting-gas of maximum explosiveness, at a velocity of 23·61 feet per second (38·24 feet at lamp), with the lamp in its normal state (1 shield and 2 gauzes), the wick-flame was extinguished; the gas continued to burn within the gauze, which became red, but only for a fraction of an inch at the base, and the lamp being vigorously agitated, no explosion occurred at the end of 5 minutes. With the lamp with shield and 1 gauze the same conditions gave the same results, proving that with only one gauze the Marsaut lamp was perfectly safe.

Modified Marsaut Lamps.—Experiments were made with the Marsaut lamp, modified by having a large opening cut in the shield 3·03 by 1·77 inches, and with another lamp with holes in the top and bottom of the shield opposite the gauze, and with other modifications. These alterations were proved by experiments to interfere materially with the safety of the lamp.

W. N. A.

THE CUVELIER LOCK FOR SAFETY-LAMPS.

Considérations sur la Question de la Fermeture des Lampes de Sûreté. By JOSEPH GOFFIN. *Publications de la Société des Ingénieurs sortis de l'École Provinciale d'Industrie et des Mines du Hainaut*, 1892, series 3, vol. i., pages 208-215, and one figure.

In the new form of the Cuvelier lock, as in the old form,* the lamp is fastened by connecting its upper and lower portions by a bolt. This bolt is vertical and is connected with a spiral spring tending to draw it down. At its upper end is a groove, into which fits the extremity of a horizontal lever, so as to keep it raised, the lever being kept in position by a strong spring. Against the lever impinges a socket, into which fits a rod with a hole down through it, which can be connected

* *Trans. N.E. Inst. Min. Eng.*, vol. xxxvi., page 51.

with a hydraulic accumulator. The pressure so exercised forces the socket forward, which reacts on the lever so as to free the head of the bolt; and this is forced down by a spring and the lamp unfastened. It can be refastened by simply raising the bolt, so that the end of the lever catches into the groove around its head. G. E. C.

RELIGHTING SAFETY-LAMPS IN COLLIERIES.

Note sur le Rallumage des Lampes de Sécurité dans les Mines. By JOSEPH GOFFIN. *Revue Universelle des Mines, etc.*, 1892, series 3, vol. xviii., pages 39-49, and plate II. (eight figures), and *Publications de la Société des Ingénieurs sortis de l'École Provinciale d'Industrie et des Mines du Hainaut*, 1892, series 3, vol. i., pages 173-187, and plate XIII.

One of the great faults of the Mueseler lamp is the ease with which it is extinguished. Exact statistics from several collieries show that 20 per cent. of the lamps in use are accidentally extinguished daily. This extinction causes great loss of time, as the lamps have to be taken to distant places to be re-lighted, and it tempts the workmen to open their lamps surreptitiously.

In order to overcome this inconvenience several methods have been devised for the interior re-lighting of lamps. The electric re-lighter of Messrs. Durant and Herbert (1881) was the first, or one of the first of these inventions. Two enamelled metal rods pass through the oil-vessel of the safety-lamp, one on each side of the wick-tube, and a thin platinum wire passing above the wick unites the two rods. The bases of the rods terminate in two buttons, intended to be applied to the poles of an electric battery so as to heat the platinum wire. To re-light the lamp the wick is raised till it touches the wire, and the bases of the rods applied to the poles of the battery; this renders the wire incandescent, and so relights the lamp. This system was adopted in one colliery, but its use has been discontinued.

The re-lighting lamp of Messrs. Mori and Rhodes is based on the same principle as the last lamp, but the details of construction are improved. In this lamp the platinum wire is of a horse-shoe shape, and is placed so as to touch the wick. The metal conductors are each made in two portions, which are kept apart by a spring; when connected with the electric battery the circuit is completed, the wire rendered incandescent, and the wick re-lighted.

The system of re-lighting lamps by electricity does not completely meet the difficulty, because the lamps require to be taken to the place where the battery is kept, and a number of batteries or accumulators have to be placed in each of the various districts of a mine.

These inconveniences are entirely overcome by the use of internal re-lighters, by which the wick is lighted either by fulminating-caps attached to a band of strong paper or by matches.

The Wolf benzine lamp is re-lighted by fulminating-caps; a narrow roll of paper to which discs of the fulminate are attached is carried in the base of the lamp, and by mechanical contrivances the paper is drawn past the wick, and a disc of fulminate ignited in proximity to it. This system is only applicable to lamps fed with volatile mineral oils such as benzine.*

The writer, however, strongly objects to the use of such volatile oils in safety-lamps.

The Catrice re-lighter† may be used in lamps burning ordinary oil. The lamp is

* *Trans. N.E. Inst. Min. Eng.*, vol. xxxiv., page 291, and plate XLI.

† *Ibid.*, vol. xxxvii., abs., page 54.

re-lighted by means of a match, which, by a mechanical arrangement described, is shoved up a tube alongside the wick, and ignited in its passage by friction. A small barrel, somewhat like the barrel of a revolver, placed in the oil-vessel, contains 13 matches, tipped with an easily-inflammable chemical composition, and these are used one after another.

W. N. A. and G. E. C.

TOMMASI ELECTRIC SAFETY-LAMP.

Nouvelle Lampe Electrique de Sécurité. By D. TOMMASI. *Revue Universelle des Inventions Nouvelles.* Edition A, 1892, pages 238-239, and figure.

In the Tommasi electric safety-lamp, the glow-lamp is enclosed in an air-tight glass cylinder, closed below by the lower part of the lamp, and above by a cover fitted with a stop-cock. In the lower part of the lamp is a pair of bellows full of air, so arranged that when full it cuts off the electric current. To light the lamp a quantity of air is forced through the stop-cock in the upper cover. The tension thus produced depresses the bellows and establishes the current. The lamp is extinguished by opening the stop-cock, which relieves the pressure, the bellows then rise, and cut off the electric current. The current is similarly cut off when the glass-cylinder is broken. If the glass globe of the glow-lamp be broken, the air inside the glass-cylinder expands, the bellows open and cut off the current as before.

G. W. B.

THE WOLF BENZINE SAFETY-LAMP.*

Ueber einige praktische Erfahrungen beim Gebrauche der Wolf'schen Benzin-Sicherheitslampe. By P., mining engineer. *Berg-und Hüttenmännische Zeitung*, 1891, vol. l., pages 193-195.

The facility with which the closed Wolf lamp (in its present perfected state) can be immediately re-lighted, and thus made use of in rescuing miners in case of serious accidents, has been proved at the explosion which took place in the Dreifaltigkeit pit, Polnisch-Ostrau, on January 3rd, 1891. The workmen were able to find their way to a place of safety, thanks to the light afforded by their lamps (which had been extinguished by the rush of gases, but which they had been able to re-kindle at once).

In addition to furnishing a stronger and steadier light than is the case with ordinary oil safety-lamps, the Wolf lamp gives more timely and more decisive indications of the presence of fire-damp; the flame can be so adjusted that a practised eye may detect the presence of 1 per cent. of the gas in the pit. But these advantages can only be reckoned with on condition of using perfectly pure, double-distilled benzine—a circumstance often overlooked in practice. O. S. E.

SALT-MINING IN THE AUSTRIAN ALPS.

Der Salzbergbau in den österreichischen Alpen. By AUGUST AIGNER. *Berg-und Hüttenmännisches Jahrbuch*, 1892, vol. xl., pages 203-230, with three plates.

After a preliminary paragraph, implying that no complete description of salt-mining in that part of Europe has been published since the appearance of Mr. Ritter von Hauenfels' paper in the *Leoben Mining Journal*, in 1853, the author proceeds to consider:—

* *Trans. N.E. Inst. Min. Eng.*, vol. xxxiv, page 291, and plate XLI.

I. The Saline Formations in the Alpine Districts.—These range from Maria Zell, in the east, to Hall (Tyrol), in the west, the rock-salt occurring mostly in the Werfen Shales, the lowest division of the Bunter Sandstone series of the Trias. The measures worked for salt are called the Haselgebirge, and are, in point of fact, a chaotic jumble of rock-salt, saline and gypseous clays, polyhalite, anhydrite, soluble magnesium and sodium sulphates, hepatite, werfen, and other shales, etc. The rock-salt is extremely variable in colour and in structure; the percentage of pure sodium chloride in it varies from 96 to 100. The polyhalite occurs in fibrous plates of an inch or more in thickness, the undersides of which have generally a covering of clay; an average of chemical analyses shows that it contains 52.9 per cent. of calcium sulphate, 9.6 per cent. of magnesium sulphate, 12.4 per cent. of potassium sulphate, 5.4 per cent. of sodium chloride, $\frac{1}{2}$ per cent. of sodium sulphate, 10.01 per cent. of aluminium silicate, and 4.2 per cent. of water.

In the Kammergut the principal mines are those of Aussee, Hallstatt, and Ischl. That of Aussee is the richest, the yearly brine-production averaging 590,000 hectolitres (13,000,000 gallons). In it 13 adits have been opened, and the greatest depth attained, which has not yet touched the footwall, is 544 metres (1,783 feet); the hanging wall is Zlambach marl, a fossiliferous stratum, containing about 8 per cent. of calcium carbonate and 7.5 per cent. of the sulphate. In the Hallstatt mine the hanging wall appears to be a breccia, in which are commingled the Zlambach marl, Hallstatt, and Dachstein limestones, and other strata broken up by the uprise of an intrusive igneous mass—identified as melaphyre. Here 15 adits have been opened; the greatest depth attained is 450 metres (1,476 feet), and the annual brine-production averages 1,900,000 hectolitres (42,000,000 gallons). In the Ischl mine, where a depth of 723 metres (2,372 feet) has been reached, though the footwall is as yet unknown, the strata occur in undisturbed succession. The adits are 14 in number, and 700,000 hectolitres (15,000,000 gallons) of brine are produced yearly.

Turning now to another district, the Hallein mine is worked in an overfold, the extent and depth of which are unknown. The strata here are reckoned to be about as rich in salt as those of Ischl; the annual brine-production averages 834,000 hectolitres (18,500,000 gallons). It is noticeable that a large proportion of magnesium chloride is present in the salt deposit. The saline measures of Berchtesgaden are practically a continuation of those of Hallein, and the brine produced from them annually amounts to 1,200,000 hectolitres (26,500,000 gallons). In that neighbourhood salt-mining is of very ancient date, and the industry was carried on under the rule of the mediæval bishops of Salzburg and provosts of Berchtesgaden. The Hall (Tyrol) mine is worked in the Keuper—that is, at a far higher geological horizon than the other mines, and the saline deposit is very poor, the maximum percentage of salt being 35. The strata appear to have been much affected here by dynamic influences, one proof of such action being the occurrence of galena in contact with the rock-salt. The greatest depth struck is 300 metres (984 feet), and the annual brine-production averages 523,000 hectolitres (11,500,000 gallons).

The author discusses at considerable length the question of the origin of the salt-deposits, and enumerates his conclusions in the following summary of the phases of formation :—

1. Evaporation (disturbed by earth-movements) of concentrated mother liquors, accompanied by vast accession of heat from the underlying strata, or even by atmospheric evaporation; and horizontal deposition of the clays.

2. Squeezing and folding of the saline beds at a later epoch, under enormous pressure.

3. Dynamic action (eruptive rocks) due to causes partly active at the surface, partly at great depths, and contemporaneous destruction of the entire complex of strata—forming the Haselgebirge measures.

4. Partial folding of the mass of the Haselgebirge, by means of lateral pressure ensuing on mountain-formation, and dynamic influences continuing active down to recent times.

II. *Method of Working the Salt-deposits.*—The salt layer, being presumably first proved by a borehole, a shaft sloping at an angle of 40 degs. is driven down to the required spot from the gallery or upper level; it is provided with a stairway and hand-rail and pipes for taking the fresh water down to the salt. The chamber cut in the rock-salt preliminary to conversion of the rock into brine is usually elliptical. Preference is given to this form, because in measures which are unequally saline the short axis of the ellipse can be made parallel to the strike of the rock-salt *débris*, with a view to a future cutting-off of the chamber. As to the methods of bringing the brine from the pit bottom, the author describes some which have a purely academic interest, for they appear to be discarded nowadays; and even of the others he remarks, on page 246, that they are all antiquated, except the Ebenwehre or horizontal system, which is the cheapest and simplest. (It is illustrated in Fig. 4, of Plate V., in the original paper.) The mechanical details in this section of the paper can hardly be summarized in the absence of the descriptive illustrations, but they do not seem, on the whole, likely to be of much practical value for the English reader. The paper, so far as published, winds up with a series of theoretical considerations, largely mathematical, on changes of volume (in salt and water) consequent on the production of brine.

O. S. E.

SALT INDUSTRY IN ITALY.

Eine neue Saline in Italien. By F. B. *Berg-und Huettenmannische Zeitung*, 1892, vol. li., pages 347-348.

The rocky island of Ischia in the Gulf of Naples is of volcanic origin, and is well-known for its hot mineral springs, the town of Casamicciola on its northern slope being a favourite watering-place. The highest hill on the island is the steep-sided Mount Epomeo, and between its southern base and the sea there is a gently inclined sandy beach called "dei Maronti" about a mile and a quarter long by 130 feet broad, which is constantly warm even below low water-mark; summer and winter it has a temperature of 122 degs. Fahr. at a foot below the surface, the heat increasing with the depth to 221 degs. Fahr. at 39 inches down. Experiments at different points, in different seasons, and in different years, have given nearly the same results. The waters of two brooks, flowing down from the mountain over this expanse, have temperatures of from 160 to 210 degs. Fahr.

On the strength of the above experiments, a company approached the Government for a concession to win salt from the sea by the aid of tanks embedded in the "dei Maronti" sand. It was shown that sea-water contained in a zinc box 39 inches square imbedded in the hot sand, evaporated within three days without boiling or bubbling, leaving all its contents of salt behind dry, and the experiment was repeated in 100 different places with a like result. The Government agreed to grant the concession, and preparations were being made to carry on the work with large tanks 39 inches deep, having their upper edges level with the sea, when the destruction of Casamicciola by an earthquake stopped the enterprise, and the concession lapsed.

It was calculated that one ton of common salt, which in Italy costs about 42s., could be sold at a profit for 12s. The sea-water round Ischia containing 26½ per cent. of common salt, and 14 per cent. of secondary salt, a basin 39 inches deep with an area of 247 acres would produce 122,000 tons of common, and 64,845 tons of secondary salt. In other Italian salt-works 41 tons of coal are burnt per 100 tons of salt produced, but at Ischia the only work required would be the opening and shutting of the sluices, the collecting of the salt when dried, and the watching of the course of the evaporation.

The temperature being constant and the boiling of the solution impossible, the common salt would first be given off and obtained almost pure. The making of the secondary salt would be easily and cheaply effected by means of the hot streams already mentioned.

The cost of making the salt is reckoned at about 2s. per ton.

A. R. L.

THE SALT LAKES OF SOUTH-WESTERN SIBERIA.

Die Salzseen von S.-W. Sibirien. By R. HELMHACKER. *Berg-und Huetten-männische Zeitung*, 1892, vol. li., pages 233-235.

In the low-lying steppes of South-Western and of the northern part of Mid Siberia is a large tract of slightly depressed country studded with numberless salt-lakes, which are gradually drying up. They are the remains of a large sheet of brackish water which once included the Aral and Caspian seas, these two latter having within a few decades themselves perceptibly decreased in area. The surface formation in these districts is a clayey sand alternating with sandy clay of a light brown or light grey colour, covered with a thin stratum of soil in which flourishes a very profuse vegetation.

The original sea having been brackish, the lakes, as they dry up, become constantly more salt, and deposit in greater or less quantities and proportions common salt (chloride of soda), bitter salt (sulphate of magnesia), Glauber salt (sulphate of soda), and other salts. Many of them deposit a thick crust of salt on their beds, which is collected round their margins in summer when evaporation diminishes their area. Other lakes again are not sufficiently salt-bearing to form such deposits.

The lakes belong, some to the Privy Exchequer of the Czar, some to the Russian State, and others to the Kirghiz.

Common salt is the kind most extensively met with, and this is dredged up or collected round the edges of the lakes and heaped up on land, to be dried and separated from sand and other impurities by the summer sun. It is sent to market in boats on the rivers Irtysh and Irtym, or in winter by sledges.

The proportion of salt in the water varies very much in different lakes, and a large number of them are not worth working, but these will become more and more salt as they dry up, and may be profitably worked at some future period.

A. R. L.

THE BROKEN HILL MINES, NEW SOUTH WALES.

On the Geological Occurrence of the Broken Hill Ore-deposits. By E. F. PITTMAN. *Records of the Geological Survey of New South Wales*, 1892, vol. iii., pages 45-49.

The geological occurrence of the Broken Hill lode presents many analogous features to the well-known saddle-formation of Bendigo, Victoria. In the latter case the strata consist of Lower Silurian slates and sandstones, contorted into

anticlines and synclines. The saddles are found at the apices of the anticlines, the legs thinning out and disappearing in depth, other saddles being found immediately underneath at greater or less depth. The reefs are associated with narrow intrusive dykes of dolerite, which have doubtless influenced their mineralization.

The Broken Hill district is composed of crystalline gneisses, passing into banded quartzites, micaceous and hornblendic schists, and garnetiferous sandstones, similarly contorted. Their age is uncertain, but, according to the late Mr. Wilkinson, they are as old as Lower Silurian, and probably older. Intrusive dykes of highly-basic diorite extend roughly parallel to the hill on both sides, the hill itself corresponding to one of these anticlines. The ridge consists of the outcrop of the lode—a mass of manganiferous iron ore. Below, in the mine, the lode is found to divide into two branches, dipping east and west respectively. The dividing rock, which has been variously spoken of as horse and intrusion, has not the character of either. Its foliations indicate that it is the cap of an anticline, and suggests that the lode itself is similar to the Bendigo saddles.

This intrusion is found at differing depths in the various mines along the hill, which is another point of similarity with the Bendigo saddles, the rocks enclosing which are contorted into curves along their line of strike as well as transversely.

The Broken Hill deposit, however, differs from the Bendigo reefs in dimensions and character of gangue and mineralization, the latter consisting of auriferous quartz with a little iron pyrites, while the former consists at the outcrop of manganiferous ironstone, succeeded by kaolin and oxidized lead ores, followed in depth by lead and zinc sulphides.

If the author's theory prove correct, both portions of the Broken Hill deposit will probably thin out and disappear in depth—fortunately as yet a remote contingency. On the other hand, it is possible that by boring through the cap of the anticline other deposits might be found more or less vertically underneath.

G. E. C.

DRAINAGE OF SINKING SHAFTS: TOMSON SYSTEM.

Creusement des puits avec épuisement par machine d'extraction, système Eng. Tomson. By A. DE V. Revue Universelle des Mines, 1893, series 3, vol. xxi., pages 225-227, and one plate.

The No. 1 shaft of the Preussen mine, near Galunen, formerly bearing the name of Gustavus Adolphus, had been commenced in the spring of 1873, but was abandoned in 1875, owing to the sudden irruption of a large quantity of water at the depth of 890 feet, the water flowing out to the surface.

The level of the water having fallen after a certain time, the pit was filled in with concrete to a height of about 150 feet, that is, to a depth of 740 feet from the surface, and it remained in this state until 1891.

There were two winding-engines with two cylinders, 31 inches and 18 inches in diameter respectively, with 61 inches and 31 inches strokes, and a strong steam-winch. The first of these machines was employed in drawing water, the second for sending down the workmen, material, and winding up of the excavated matter; the winch was used for working a movable platform suspended in the shaft.

The main difficulty was to fill the kibble rapidly and completely, and to keep the bottom of the sinking free from a quantity of water not exceeding 50 gallons per minute. This difficulty was overcome by the installation, at some feet from the bottom, of sheet-iron tanks, into which the water-tubs dipped, these tanks being kept full by means of a pulsometer pump suspended at the bottom of the shaft.

The water-tubs were guided by two small steel-wire ropes, which were also used to support the sheet-iron tanks. At the surface these ropes passed over pulleys to the steam-winch.

The water-tanks were connected at the bottom, and were a few inches greater in diameter than the water-tubs, and about 3 feet longer.

The pulsometer pump was placed on the same cradle as that supporting the tanks, or it might be suspended by a special rope from the winch at the surface. Having to raise the water only a small height the pulsometer pump acted excellently under these conditions. The steam was carried to it by a 2½ inches wrought-iron pipe well covered.

The whole of the installation could be lowered proportionally as the depth of the sinking increased, or raised to the surface again, when it was desired to clear the whole of the pit at any time.

The shaft was opened from a depth of 740 to 850 feet, and the walling completed, drawing at the same time a feeder which finally increased to 300 gallons per minute.

R. A. S. R.

THE POETSCH METHOD OF SINKING.*

Ein neuer Erfolg des Pötsch'schen Gefrierverfahrens beim Schachtabteufen. By W. SCHULZ. *Glückauf*, 1892, vol. xxviii., pages 1053-1056.

In the middle of October, 1892, the author (then visiting the Lens collieries in Northern France) went down No. 10 shaft, which had been successfully sunk to the coal-measures by the Poetsch freezing-process; and at the same time he saw the process in actual operation in the No. 10 bis shaft, which is just 100 feet distant from the first-mentioned shaft.

The strata through which both shafts were sunk, down to about 138 feet from the surface contain a good deal of water. In descending order we have 32 feet of alternating sands and sandy and marly clays; and then 100 feet of Cretaceous rocks, consisting partly of soft, clayey chalk, and hard, much-jointed, loose chalk with flints, and partly of massive beds of very hard chalk; below this comes an absolutely impermeable layer of clay, overlying a water-bearing blue marl (which yields from 3 to 3½ cubic feet per minute). The sequence of the strata had been ascertained by means of a boring to a depth of 264 feet.

In sinking shaft No. 10 the ordinary methods were at first used; cast-iron tubbing, 1 inch thick, and 15½ feet in inside diameter was put in resting on three wooden wedging-cribs, and the space betwixt the iron tubbing and the outer wall of masonry was filled with concrete. The iron tubbing was built up of 39 inches rings, six segments to each ring, and was continued below by a tubbing of oaken timber (about 6 inches thick). The sinking was then carried on by piling, but at a depth of 84 feet from bank, the shaft was flooded and filled with mud through the breakage of a piece of timber on the north side of the shaft. The inrush of water increasing to 875 cubic feet per minute, and the rate of progress of the sinking during the preceding fortnight having been practically *nil*, the engineers decided to resort to the Poetsch process. The pumps were accordingly withdrawn, 8 boreholes were pierced within the area of the shaft, and 20 without it, down into the above-mentioned blue marl, to a depth of 5 feet below the clay which upholds the water and 136 feet from the surface. This was done by a method of cable-boring invented by Mr. Reumaux, the manager of the Lens collieries, and the holes were lined temporarily with tubing which was taken out after the freezing pipes had been

* *Trans. Fed. Inst. Min. Eng.*, vol. ii., page 441, and plate XII.; and vol. iii., page 1023.

placed in position. The freezing liquid was a solution of chloride of calcium cooled by an Osenbrück ammonia-refrigerator; the liquid was led into the freezing-pipes at an initial temperature of 20 degs. Fahr., which was reduced later on to a minimum of 2 degs. Fahr., and was pumped back to the refrigerator at temperatures of 27 degs. Fahr. and 7 degs. Fahr. respectively. The process of freezing went on for 203 days, but the sinking operations were not started till the 228th day. Mr. Reumaux calculated that the beds which were frozen contained about 40 per cent. of water.

The sinking in the frozen mass was carried on partly by means of shot-firing, and when the blue marl had been reached the innermost freezing-pipes were removed. Cast-iron tubing, 15½ feet in inside diameter, was now put down in two lengths of 73 and 29 feet respectively, having 10 segments and 140 screwbolts to each 5 feet ring. The thickness of the upper portion of the tubing was 1.33 inches of the lower portion 1.66 inches.

After the completion of this tubing, instead of the strata being allowed to thaw the sinking was continued through grey and blue chalk marl down to 172 feet from bank, whilst the freezing solution was made to circulate as before, through the outermost pipes which had not been removed. From this chalk marl water flowed into the shaft at the rate of about 3 cubic feet per minute, but the waters from the overlying strata were completely shut off. The cast-iron tubing being completed down to the 172 feet level, the frozen strata were thawed by leading steam through the pipes, and these were then taken out. The sinking thereafter progressed without any noteworthy occurrence, and, at the time of the author's visit, No. 10 shaft was in coal-measures at a depth of 570 feet; the inflow of water at this depth was only 1 cubic foot per minute.

The Poetsch process was made use of from the first in sinking No. 10 bis shaft; 54 days were occupied in the preliminary borings, etc., and the process of freezing was continued for 75 days. The sinking was carried on by means of blasting with compressed black powder; the gunpowder fumes were taken off by an air-channel which communicated with a chimney on the surface. The structural arrangements were, on the whole, much the same as in No. 10 shaft: cast-iron tubing, 12 feet in internal diameter, and wooden wedging-cribs were used. In the middle of October, 1892, the shaft was yet being deepened; it was lighted by electric (incandescent) lamps, and six-hour shifts of eight men each were busied in building up the tubing. The temperature in the shaft varied between 23 and 25 degs. Fahr., and it was not the intention of the engineers to thaw the frozen strata until the shaft had been carried down to a depth of at least 170 feet from the surface.

No. 10 bis shaft was completed in 220 days, or an average advance of 0.66 foot per diem, a result which, under the circumstances (water-feeder of 850 cubic feet per minute) was marvellous.

In November, 1892, another shaft was being sunk by the Poetsch process in the Pas de Calais, at the Dourges collieries.

The drowning of No. 10 shaft up to sea-level had the result of providing the shaft with sufficient resistance to withstand the crushing-in pressure of the rocks (whilst arrangements were being made to restart the sinking by the Poetsch process), and the author suggests that in similar cases which may arise in the future, it would be advantageous to flood a shaft by artificial means. Further, he draws attention to the following conclusions:—

1. Hard, dense rocks offer no obstacle to the freezing process. The much-jointed loose chalk was frozen into so firm a mass that blasting was found necessary to break it down.
2. Neither walls nor iron tubing suffer from the frost.

3. The chances of ill-success with the Poetsch process are largely obviated if, as in the case of No. 10 and No. 10 bis shafts, the freezing process is only put an end to after the provision of a sufficiently high foundation beneath the ice wall or mass of frozen strata.
4. Clayey bands alternating with sandy or stony beds constitute a distinct disadvantage, for the clay freezes much more slowly and freezes less hard than the other strata. Herein practice confirms the experiments of Mr. Alby.* Indeed, plastic clay on freezing assumes a shaly structure, and in cases where it alternates with sands, the dissimilar behaviour of the strata induces breakage of the freezing-pipes. Breakages could perhaps be avoided if the lining-tubes of the preliminary boreholes were left in place instead of being withdrawn, so that the freezing-pipes within them would be throughout in direct contact with a sheet of ice. Another disadvantage of alternating sands and clays or other strata is the production of fissures in the ice-wall, but it is fair to state that in the two sinkings above described such fissures have had no injurious effect worth mentioning.
5. Mr. Reuniaux stated that an additional advantage of the Poetsch process consisted in its small cost, but sufficiently full data in support of this assertion are not, so far, forthcoming. O. S. E.

COAL-SCREENING IN THE UNITED STATES.

The Iron Breaker at Drifton, with a Description of some of the Machinery used for Handling and Preparing Coal at the Cross Creek Collieries. By ECKLEY B. COXE. Transactions of the American Institute of Mining Engineers, 1890, vol. xix., pages 398-474, and 43 plates.

Anthracite coal as it comes from the mines is not marketable, owing to the fact that it will not burn freely unless the lumps are practically of a uniform size. In addition, a considerable quantity of shale occurs with the pure coal. Slate coal is lumps composed partly of slate (shale) and partly of coal, the latter in large masses. On breaking these, pieces of pure coal of marketable size can be obtained economically. Bone coal consists of shale and coal so interstratified that they cannot be separated economically by mechanical preparation.

The coal coming from the mines is first tipped on to a fixed bar-screen, and the large coal passed by shoots on to a movable bar-screen; the small coal falling through both screens is collected together for further treatment. Up to this stage only two sizes are made, each of which is treated separately. The large coal is divided into three sorts—(a) shale and slate, which goes to the dirt-heap; (b) pure coal, sold as lumps if there is any market for it; (c) slate coal, too impure to go to market in its existing condition. Sometimes the shale can be chipped off with a pick, but more generally the mixture has to be crushed by rolls and the product sized by screens, the dirt being removed by hand-picking from the larger qualities and by washing from the smaller ones. The pure coal is also passed through rolls and afterwards sized by screens.

The small coal that passes through the fixed and movable bar-screens is conveyed to two screens, each of which makes three sizes, called "steamboat," "broken," and "egg." The small coal passes to another pair of screens, known as the stove or wet screens. The steamboat coal from both screens passes *via* a picking-shoot to a loading-shoot, provided all this quality can be sold; if it cannot, a portion is passed through a set of rolls and separated by screens into "broken,"

* *Annales des Mines*, series 3, vol. xi., page 55.

"egg," "stove," "chestnut," "pea," buckwheat No. 1, No. 2, and No. 3, and dust. All the coal which passes to the stove or wet screens, is there divided into seven of the sizes above-mentioned, ranging from "stove" to dust, or rather slime, as these screens are worked wet, *i.e.*, a large amount of water is put on them. All the wet coal from these screens is cleaned in jigging coal-washers of the Lührig type.

The rolls employed for breaking the coal differ from those generally adopted, inasmuch as the teeth are continuous from one end to the other. There are no pointed teeth, as it is found that these have a tendency to split up a lump of coal into small pieces in the same way that the blow of a pick does. It has also been found advisable to use a separate set of rolls to break each size, as if a piece of any size is simply broken as nearly as possible into two (for the next size), the amount of small coal made is much less than if the same size were struck near the centre with a pick and broken into a number of fragments. The production of "dust" is avoided as much as possible, as it is quite unsaleable.

The movable bar-screens are a modification of the Briart screen. Each screen consists of a series of double bars placed sufficiently far apart to allow coal of the required size to pass through. Each set of bars is driven by an eccentric, and one set is always below the second set when moving forward, but above when moving backward. In the Briart screen the shafts which carry the bars rise and fall the same distance as they move forward, while in this construction they only move up and down half as much as they move forward. It was found that with the Briart construction the coal was thrown up and down too much when it was fed forward with any rapidity.

Perhaps the most interesting feature is the movable screen designed by Mr. Cox, where the screening surface is approximately horizontal, but the motion and action is similar to that which a moulder gives to a sieve when screening sand. Although such screens have been used in small sizes in metal-mining, the chief difficulty in constructing a large gyrating screen making a number of sizes was to support it so that it would gyrate easily and safely, and at the same time be self-contained, so that the centrifugal force will be counterbalanced and will not shake the building. This has been done by a method which essentially consists in supporting one horizontal plate upon another by means of three or more double cones, while the motion of gyration is given to the upper plate by a crank upon a shaft passing through and journalled in the lower plate. Some of these double gyrating-screens have 4 to 8 shelves put in, make from 5 to 9 sizes, and weigh 10 tons; the screening-surfaces have always circular holes, varying from $5\frac{1}{4}$ inches to $\frac{1}{16}$ th inch in diameter. The inclination of the shelves is slight, varying from $\frac{1}{8}$ th inch to the foot (for the largest size) to $1\frac{1}{4}$ inches to the foot (for the dust.)

The automatic slate-pickers which are used depend for their action on the fact that while the coal generally breaks into cubical masses, the pieces of shale of the same length and width are of much less thickness. Hence, if a quantity of coal and shale has been passed through a screen and properly sized, the shale, if placed edgewise, would drop through a slit over which the coal would pass. The shale-pickers consist of a series of V-troughs, one side of the V being shorter and at right angles to the other. The lower half of the casting has a taper slit in the short side, and these slits widen as they approach the lower end. This is an important point, as if the slits were made parallel they would soon clog.

The height of the breaker from the railway track to the point where the coal is tipped is 79 feet, and the greatest amount of coal which has been screened and cleaned is a little over 260 tons per hour, but the breaker has not been running long enough to determine its maximum capacity. No costs are given. H. W. H.

MINERS' CHANGING AND WASH-HOUSES.

Beschreibung einiger Wohlfahrtseinrichtungen auf der Königlichen Steinkohlen-grube Dudweiler bei Saarbrücken. By—FABIAN. *Zeitschrift für das Berg-, Hütten-, und Salinen-Wesen im Preussischen Staate*, 1892, vol. xl., pages 493-501.

All the buildings are situated close to the shaft, and are so arranged that the miners are only exposed to the outside air for a short time. There is a large waiting-room, which communicates on one side with the lamp-room and on the other with a refreshment bar, where coffee and bread can be obtained at moderate prices. Connected with this room is the changing and bath-room, 108 by 64 feet, and 16½ feet high. The baths are cells fitted with a warm-water douche, and the room contains in all 55 cells, each capable of holding two men. The walls of the cells are made of corrugated iron, and there is a wooden partition in front of the baths, shutting them off from the rest of the room. The room is also fitted with a few cold-water douche-baths. Between two rows of bath cells a railing is fixed to which ropes passing over pulleys near the ceiling are attached. There is a hook at one end of the rope on which the miner may hang his clothes and then pull them up to the top of the building. Each man has his own particular hook which is numbered. It is found that the clothes dry more quickly when pulled up into the warm air near the ceiling.

The water is warmed by steam to a temperature of 95 degs. Fahr., and if the temperature sinks below this, the fact is notified by the ringing of an automatic electric-bell. Each bath requires about 7 gallons of water. The time allowed for the use of a bath for two men is five minutes. The present arrangements allow 1,200 workmen to bathe themselves in one hour. Out of 2,340 workmen 865 use the bath-house regularly.

The cost of the bath-house was £2,144, or £39 per bath or cell.

Special mine-waggons are used for men meeting with an accident. These waggons are fitted with springs and cushions, and are made so as to go into the cage.

The following articles are kept in a house close to the shaft for use in case of an explosion:—(1) One small machine-ventilator on wheels, and fitted with carrying bands; (2) 100 yards of zinc air-pipes, with a few bends, hanging wire, and cloth for plugging holes; (3) rolls of brattice-cloth; (4) saws, picks, hammers, and nails; (5) three small hand-ventilators; (6) 100 yards of small pipe for the hand-ventilators; (7) water-bottles and straps; (8) vinegar for filling the water-bottles; (9) notebooks and pencils; (10) torch-lamps for surface lighting; (11) small pipes, screws, tools, etc., for ventilating and pumping requirements; (12) a portable fire-engine with hose.

W. F. W.

SULPHUR ON PIT-HEAPS.

Sur des échantillons de soufre provenant de la houillère du Perron (Ougrée.) By A. COCHETEUX. *Annales de la Société Géologique de Belgique*, 1885-86, vol. xiii., *Bulletin*, pages 140-141.

The author, noticing a strong odour of sulphurous acid gas proceeding from a pit-heap at Perron, examined the heap, and found, just below the surface, sulphur varying from lemon-yellow to orange in colour, and forming long needles and spherical agglomerations. The materials composing the heap were pyritous shales from the Coal-measures, and ashes and clinker from the boiler-grates. The sulphur had been liberated probably by reaction taking place between the oxygen of the air, the sulphides, the organic matter, the water, and the carbon dioxide present.

O. S. E.

THE SULPHUR-MINES OF ALTAVILLA-IRPINA, ITALY.

Zur Geologie von Unteritalien, Das Schwefelbergwerk von Altavilla-Irpina in Unteritalien. By W. DEECKE. *Neues Jahrbuch für Mineralogie, etc.*, 1891, vol. ii., pages 39-48.

The Altavilla-Irpina mines are situated in the valley of the Sabato, about equidistant from Avellino and Benevento (7 miles) and are worked by a company. A new junction-railway between Avellino and Benevento will shortly be opened, and the line passes close by the works. Boys and girls are employed for the lighter duties in the refinery; work is carried on for nine months out of the twelve.

The strata in the Sabato valley are of Pliocene age; they are bounded by the Nummulitic limestones of Petruro and those of Monte Vergine. The sulphur occurs in a greasy bituminous clay, overlain by very thick conglomerates, with which are intercalated sandstones and more or less sandy marls.

The sulphur-deposits are of great thickness, and the beds beneath them have not yet been struck; the sulphur occurs in ramifying veins in the clay, or in lumps or nodules amidst the abundant lenticular masses of gypsum. As the clay becomes more bituminous the sulphur-contents diminish in quantity. Fragments of stems and branches, now converted into lignite, occur, but no other fossils have been found. It is presumed that the sulphur has been separated out from the gypsum by the slow decomposition of the organic matter present in the clay. O. S. E.

MACHINE FOR SHAPING MINING TIMBER.

Note sur la Machine à Façonner les Bois des charbonnages de Sars-Longchamps et Bouvy. By ALFRED MATHIEU. *Revue Universelle des Mines, etc.*, 1892, vol. xxiii., pages 50-52, and 5 figures.

The machine described is a circular saw with the addition of a special tool for shaping the ends of the timbers. This tool is carried on the same shaft as the saw. The machine is worked by a belt from a steam-engine and makes 1,200 revolutions per minute. One workman can shape 3,000 pieces per day, as much as eight men could do if the shaping was done in the mine, besides which all the waste-material remains on the surface and can be utilized. W. N. A.

TELETHERMOMETERS.

Zwei neue Fernthermometer. By HANS HARTL. *Zeitschrift des Vereines Deutscher Ingenieure*, 1891, vol. xxv., pages 1399-1401.

Two instruments are described, intended to indicate temperatures at a distance. The principle of their construction is that the saturated vapours of ether and alcohol respectively or of ether-cum-alcohol, increase much more rapidly in tension with increasing temperature than does atmospheric air.

One of the instruments, consisting of a V-shaped glass tube, contains mercury in its two branches; on to the surface of the liquid metal in one branch a few drops of ether are brought, and there is an alarum connected with the instrument, indicating to the observers placed in another room when the previously-fixed limiting temperatures have been reached, between which the temperature of a given space is sought to be maintained.

The second instrument is provided with a constant indicator in the shape of a Wheatstone bridge-arrangement. O. S. E.

CENTRIFUGAL VENTILATORS.
Centrifugal Ventilators. By R. VAN A. NORRIS. *Transactions of the American Institute of Mining Engineers*, 1891, vol. xx., pages 637-677.
 The following Table of Fan Experiments is recorded:—

Number of Fan.	Experiment.	Owner and Location.	Type of Fan.	Diameter.		Width.	Number of Inlets.	Diameter of Inlets.	Shutter?	Revolutions per Minute.		Cubic Feet of Air per Minute.	Water-gauge.	Horse-power in Air.	Indicated Horse-power of Engine.	Efficiency of Engine and Fan.	Remarks.		
				Ft. In.	Ft. In.					Engine.	Fan.								
1	A	Susquehanna Coal Company, Double fan	Gulbal	20	0	6	0	4	8	10	Yes	42	84	236,684	1.80	67.13	88.40	75.9	Two fans on separate shafts, driven by a pair of 20 in. by 36 in. engines, belted to drive 3 to 1, with two 24 in. 8-ply rubber belts.
	B	do.	Double	..	..	..	..	..	..	..	..	50	100	336,862	2.50	132.70	155.43	85.4	Each fan has two inlets and a sheet-iron disc.
	C	do.	..	..	..	..	..	..	..	..	..	5.1	100	238,080	2.60	131.94	143.42	85.02	
	D	do.	..	..	..	..	..	..	..	..	..	55.1	111	347,396	3.30	175.17	209.64	83.6	
	E	do.	..	..	..	..	..	..	..	..	..	61.4	123	394,100	3.60	223.56	195.21	75.7	
	F	do.	..	..	..	..	..	..	..	..	..	50	100	188,888	1.40	41.67	97.99	43.6	
2	A	Susquehanna Coal Company, No. 6 slope	Gulbal	20	0	6	0	2	8	10	No	59	59	59,587	1.30	11.27	16.76	67.83	Same as No. 1 fan, except tips of blades radial. No shutter, no disc.
	B	do.	..	..	..	..	..	..	..	..	..	83	83	82,969	2.15	27.86	48.54	67.38	Pair 16 in. by 24 in. Single opening, 24 in. by 32 in. engine.
3	A	Susquehanna Coal Company, Ross seam, No. 2 shaft	Gulbal	25	0	8	0	1	11	6	Yes	40	40	49,611	0.87	6.80	13.83	49.2	
	B	do.	..	..	..	..	..	..	..	..	..	70	70	137,760	2.55	55.35	67.44	82.07	
4	A	Susquehanna Coal Company, Lee seam	Gulbal	25	0	8	0	1	11	6	Yes	62	62	225,238	1.45	51.44	62.93	81.74	Same as No. 3 fan. Single inlet. Blades flat, 18 in. by 36 in. engine.
5	A	Delaware and Hudson Canal Company, Baltimore Tunnel	Gulbal	17	6	4	0	4	8	0	No	..	28	63,337	0.10	1.07	..	..	Fans run with throttle full open, and 75 per cent. of boiler pressure assumed as mean effective pressure. Two fans on same shaft. Pair 16 in. by 30 in. engines, 24 in. belt, 14 in. by 24 in. engine.
	B	do.	Double	..	..	..	..	..	..	..	..	..	..	..	..	..	..		
	C	do.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..		
	D	do.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..		
6	A	Union Coal Company, Pennsylvania Colliery	?	18	0	6	4	2	8	0	No	80	80	66,560	1.35	14.13	23.60	60	
	B	do.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..		
	C	do.	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..		
7	A	Mineral Railroad and Mining Company, Cameron Colliery	Gulbal	18	0	4	11	2	8	0	No	56	110	71,590	2.45	18.00	30.80	59	18 in. by 36 in. engine.

CENTRIFUGAL VENTILATORS.—Continued.

Number of Fan.	Experiment.	Owner and Location.	Type of Fan.	Diameter.		Width.	Number of Inlets.	Diameter of Inlets.	Shutter?	Revolutions per Minute.		Cubic Feet of Air per Minute.	Water-gauge.	Horse-power in Air.	Indicated Horse-power of Engine.	Efficiency of Engine and Fan.	Remarks.
				Ft. In.	Ft. In.					Engin.	Fan.						
8	A	Lehigh and Western Baltimore Coal Company, Stanton old fan	Guibal	35 0	11 8	..	1	17 6	No	46	46	223,850	1.96	70.62	98.45	71.73	20 in. by 48 in. engine.
9	A	Lehigh and Western Baltimore Coal Company, Stanton new fan	Guibal	35 0	11 8	..	1	17 6	No	46	46	224,830	1.85	63.46	94.60	72.37	20 in. by 48 in. engine.
	B	do.	..	..	..	..	..	..	..	55	55	277,380	2.75	92.93	159.02	57.81	..
10	A	Lehigh and Western Baltimore Coal Company, Empire	Guibal	24 0	10 0	..	1	12 0	No	66	66	134,662	1.95	41.38	63.70	66.00	17 in. by 36 in. engine.
	B	do.	..	..	..	..	..	..	..	73	73	194,300	2.50	75.69	101.07	76.69	..
11	A	Lehigh and Western Baltimore Coal Company, S. Wilkes-Barre	Capell	12 6	12 0	..	2	7 4	No	50	150	177,880	1.35	37.70	90.10	41.80	24 in. by 36 in. engine.
	B	do.	..	..	..	..	..	..	..	60	180	215,200	1.85	56.00	123.00	45.30	..
11½	A	Lehigh and Western Baltimore Coal Company, Hollenback	Guibal	35 0	11 8	..	1	17 6	No	45	45	217,338	2.25	77.05	84.4	91.30	20 in. by 48 in. engine. This efficiency is doubtful.
	B	do.	..	..	..	..	..	..	..	50	50	257,690	2.40	97.40	131.3	74.20	..
12	A	East Howle Colliery, Durham, England	Capell	12 0	10 0	..	2	7 0	No	50	200	183,198	3.35	70.30	102.79	68.40	Fair engines, 20 in. by 36 in. One 24 in. belt. Driving 4 to 1.
	B	do.	..	..	..	..	..	..	..	50	500	156,510	3.30	81.35	113.61	71.60	..
	C	do.	..	..	..	..	..	..	..	50	500	180,809	3.05	86.89	129.07	67.30	..
	D	do.	..	..	..	..	..	..	..	50	500	205,150	2.80	92.50	150.08	61.70	..
13	A	South-West Coal and Coke Company, Do.	Guibal	25 0	8 0	..	1	1 0	No	10	10	28,895	0.10	0.45	1.30	35'	20 in. by 36 in. engine.
	B	do.	..	..	..	..	..	..	..	20	20	57,120	0.20	1.80	3.70	9'	..
13½	C	Morewood Mine	..	..	..	..	..	..	..	25	25	66,640	0.29	2.90	6.10	48'	..
	D	do.	..	..	..	..	..	..	..	30	30	73,080	0.10	4.60	9.70	47'	..
	E	do.	..	..	..	..	..	..	..	35	35	94,080	0.50	7.40	15.00	48'	..
	F	do.	..	..	..	..	..	..	..	40	40	112,000	0.70	12.30	24.90	49'	..
	G	do.	..	..	..	..	..	..	..	60	60	132,700	0.90	18.80	38.80	48'	..
	H	do.	..	..	..	..	..	..	..	70	70	173,000	1.25	29.30	66.40	65'	..
	I	do.	..	..	..	..	..	..	..	80	80	207,000	1.40	37.00	107.10	74'	..
	J	do.	..	..	..	..	..	..	..	80	80	222,340	2.26	75.80	152.60	52'	..

CENTRIFUGAL VENTILATORS.—Continued.

Number of Fan.	Experiment.	Owner and Location.	Type of Fan.	Diameter.		Width.	Number of Inlets.		Diameter of Inlets.		Shutter?	Revolutions per Minute.		Cubic Feet of Air per Minute.	Water-gauge.	Horse-power in Air.	Indicated Horse-power of Engine.	Efficiency of Engine and Fan.	Remarks.
				Ft. In.	Ft. In.		Ft. In.	Ft. In.	Engine.	Fan.									
14	A	Lehigh Valley Coal Company, Dorrance Colliery	Guthbal	35	0	12	0	1	17	6	No	48	48	177,000	2.25	62.70	83.30	76.2	24 in. by 42 in. engine.
15	A	Lehigh Valley Coal Company, Henry Colliery	Guthbal	30	0	10	0	1	15	0	No	45	45	245,000	1.35	52.12	60.22	86.85	30 in. by 48 in. engine.
16	A	Lehigh Valley Coal Company, Facter No. 5	?	20	0	6	0	1	12	0	No	58	58	84,149	0.35	12.60	23.04	54.25	17 in. by 24 in. engine.
17	B	do.	..	..	..	..	..	..	..	..	..	80	80	117,573	1.80	33.35	54.60	61.00	Fan fitted with Walker shutter, 20 in. by 30 in. engine.
17	A	Pleasley Colliery, Lancashire, England	Guthbal	24	0	8	0	..	..	..	Yes	70	70	85,285	2.44	32.74	40.90	80.18	
17	B	do.	..	..	..	..	..	..	..	..	..	80	80	98,512	3.03	46.56	61.12	76.17	
18	C	do.	..	..	..	..	..	..	..	..	..	90	90	107,390	3.55	61.71	82.12	75.14	14 in. by 30 in. engine.
18	A	Delaware, Lackawanna, and Western Railroad, Avondale	Open	12	0	3	4	2	6	0	..	124	26	17,640	0.08	0.23	0.63	36.80	
18	B	do.	..	..	..	..	..	..	..	..	..	25	52	29,498	0.25	1.16	2.33	49.87	
19	C	do.	..	..	..	..	..	..	..	..	..	60	104	51,942	0.70	5.72	12.38	46.26	The air measurements in all the Delaware, Lackawanna, and Western Railroad Company's experiments were made with the anemometer held stationary in centre of airway, giving quantities of air much too high. Shutter. Engine 16 in. by 30 in.
19	A	Delaware, Lackawanna, and Western Railroad Company, Bellevue	Open	16	0	4	6	2	8	0	..	57	110.6	132,852	1.80	38.09	58.92	64.00	
19	B	do.	..	..	..	..	..	..	..	..	..	59	114.5	162,714	1.60	40.87	58.71	69.00	
19	C	do.	..	..	..	..	..	..	..	..	..	57	110.6	188,146	1.20	35.57	68.00	61.40	
19	D	do.	..	..	..	..	..	..	..	..	..	58	112.6	132,188	1.30	45.56	68.15	66.8	
19	E	do.	Closed	..	..	..	..	..	..	..	Yes	58	112.6	142,159	1.60	35.84	51.52	69.5	
19	F	do.	Closed	..	..	..	..	..	..	..	..	58	112.6	145,885	1.75	40.22	54.22	74.2	
19	G	do.	Open	..	..	..	..	..	..	..	..	112	..	None	1.35	..	..	0	
19	H	do.	Closed	..	..	..	..	..	..	..	Yes	..	..	..	2.30	..	..	0	
19	I	do.	Closed	..	..	..	..	..	..	..	..	112	..	..	2.57	..	..	0	
19	J	do.	Open	..	..	..	..	..	..	..	No	57	110.6	136,387	1.20	25.78	..	..	
19	K	do.	Closed	..	..	..	..	..	..	..	..	57	110.6	147,488	1.60	39.01	..	..	
19	L	do.	Closed	..	..	..	..	..	..	..	Yes	57	110.6	143,597	1.30	33.94	..	..	

CENTRIFUGAL VENTILATORS.—Continued.

Number of Fan.	Experiment.	Owner and Location.	Type of Fan.	Diameter.	Width.	Number of Inlets.	Diameter of Inlets.	Shutter?	Revolutions per Minute.		Cubic Feet of Air per Minute.	Water-gauge.	Horse-power in Air.	Indicated Horse-power of Engine.	Efficiency of Engine and Fan.	Remarks.
									Engine.	Fan.						
20	A	Delaware, Lackawanna, and Western Railroad Company, Holden fan	Guibal	25 0 8 0	8 0	2	12 6	No	43	43	135,600	0.70	14.96	23.95	62.5	18 in. by 36 in. engine.
21	B	do.	..	..	..	..	..	..	43	43	113,140	0.80	14.25	23.85	62.4	Mine choked.
	C	do.	..	..	..	..	..	..	40	40	124,510	0.47	14.56	20.71	70.3	Mine doors open.
	A	Delaware, Lackawanna, and Western Railroad Company, Dodge fan	Open	16 0 4 6	4 6	2	8 0	..	48	88.6	177,555	0.85	23.22	43.97	54.2	Mine normal. 18 in. by 36 in. engine.
22	B	do.	Guibal	..	..	..	..	..	60	110.8	201,135	1.10	34.26	70.49	49.5	Mine normal. 18 in. by 36 in. engine.
	C	do.	..	..	..	..	..	..	48	83.6	231,225	0.75	27.33	44.93	60.8	Mine doors open.
	A	Coxe Brothers and Co., No. 2 slope, Drifton	..	30 0 6 0	6 0	1	7 0	Yes	62	62	51,084	1.00	8.05	19.82	40.62	Engine 16 in. by 24 in.
23	A	Philadelphia and Reading Coal and Iron Company, Henry Clay Colliery	Guibal	21 0 7 2	7 2	1	10 6	No	70	70	125,000	0.85	16.5	73.00	23	Engine 14 in. by 36 in. Air measurements taken in same manner as for fans 14, 20, and 21.
24	A	Philadelphia and Reading Coal and Iron Company, Mahanoy City Colliery	Guibal	15 0 5 2	5 2	1	7 6	No	100	100	65,000	1.60	16.4	68.00	24.1	Engine 12 in. by 30 in.
25	A	Philadelphia and Reading Coal and Iron Company, W. Bear Ridge Colliery	Guibal	18 0 6 2	6 2	1	9 0	No	80	80	81,000	2.75	34.67	63.00	59.6	Engine 16 in. by 18 in.

M. W. B.

THE EDUCATION OF MINING ENGINEERS.

BY J. H. MERIVALE.

The need of a thorough training for mining engineers has been recognized upon the Continent for very many years. The first mining school established was, the author believes, that of Schemnitz, in Hungary, founded in 1760. This was followed by the establishment of similar schools at Freiberg, Paris, and at most, if not all, of the more important mining centres of the Continent. It was not, however, until 1851 that the first mining school—the Royal School of Mines, Jermyn Street—was established in England; and this good step has been tardily followed, until at last, more than one hundred years after our Continental rivals, we have science colleges, each with its mining department, fairly well distributed throughout the country. Whether these colleges are liberally supported or not, both with money and students, it is not the purpose of this paper to discuss.

The author has been struck with the ignorance of many persons, capable of devoting the necessary time and money to a thorough training in mining: ignorance both of the kind of education required, and of the opportunities now offered for obtaining it; and he has been fortified in this view by a request from the secretary (Mr. M. Walton Brown) for a paper upon the education of mining engineers. He has thought therefore that a schedule of the courses of study provided for mining students at some of the most important of the mining schools of the world, prefaced by a short paper embodying his own views upon this important subject, might be acceptable to the members of the Institute.

The schedule of courses has involved much labour, and he wishes here to thank Mr. Ritson, himself an old student of the Clausthal school, for his very kind assistance; and the secretary of the Institute, who, if he imposed this task upon him (the author) has ably assisted him in carrying it out.

The mining student should receive the usual education of an English gentleman, and should pass the examinations in general education

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required by all the professions, excepting that of the engineer. This is not only expedient, but necessary, as the universities require it for their science degrees. He would then be about sixteen years of age, and should leave school and go through a two years' course of pure science at one of the science colleges, taking a diploma at the termination of the course. At the same time he should at least keep up his French, German, and drawing, though he will not have the time to make much advance in these important subjects.

At eighteen years of age he should be old enough to definitely decide upon his profession. If he determines after all not to become a mining engineer, the education he has received will be equally good for almost any other profession. It is a mistake to differentiate too early, and the author has observed this mistake to be made over and over again.

Having decided to be a mining engineer the student must then select a colliery for his five years' apprenticeship. This is an important matter; the colliery should be one where varied work may be seen and, what is still more important, where the viewer has had some experience in training youths, and is willing to take some trouble with them.

Trailing round the pit behind an overman is not putting the time to the best advantage. Each department should be taken in turn, and the youth should himself do the work, so far as he can. Let him be put in charge of an intelligent deputy-overman, take the regular deputy-overman's shift, and really assist in the work, and the same with rolleywaymen, shifters, cashier, storekeeper, etc. If he is strong and is careful not to overdo it, he will be the better for a few weeks' coal-hewing.

He should try to get a little reading, and if he has a taste for science should devote a few hours regularly each week to this, so as to take his B.Sc. Great facilities are offered at the Durham College of Science in the shape of evening lectures, etc., to apprentices desirous of combining a little science with their practical work.

At the end of three years the student should have obtained an accurate practical knowledge of mining in all its details, as practised under one or two sets of conditions. He should now try to get wider views; and this he can best do by going abroad for twelve months, spending six months, say, in France or Belgium, and six months in Germany. He should select mines where the conditions are dissimilar from those to which he has been accustomed, and must be careful not to visit too many pits—some half-a-dozen—*i.e.*, two months at each will be quite enough. He should take copious notes, and neither speak, read, nor write a word of English during his stay abroad.

On his return to England he must, in accordance with the requirements of the examining board, hold some official position for twelve months, that of back-overman is perhaps the best, giving as it does great opportunities of gaining practical experience. He will now be twenty-three years of age and should sit for his certificate, which he will have no difficulty in obtaining.

For the first few years of his professional life, the young colliery manager will probably not have a very large practice, and he may wisely devote some time to further study : take his M.Sc., or even the D.Sc., and write papers for the mining institutes.

In conclusion, the author would wish to point out that though a man must live, money is very far from everything, and each one in youth should devote some portion of his time to the acquirement of those arts without which life for most of us would not be worth having. The mining engineer who neither smokes, photographs, nor fiddles, nor has cultivated any art outside his profession, is only half a man, though he be a D.Sc. of Durham University, and have the biggest practice in the kingdom. And the author is happy to say that some at least of these extra professional pursuits are cultivated in the Durham College of Science.

APPENDIX.

EDUCATIONAL INSTITUTIONS WHERE COURSES OF STUDY ARE PROVIDED FOR MINING AND METALLURGICAL ENGINEERS.

THE ROYAL COLLEGE OF SCIENCE, LONDON, WITH WHICH IS INCORPORATED THE ROYAL SCHOOL OF MINES.

The Royal College of Science at South Kensington is supported by the State, to supply systematic instruction in the various branches of physical science to students of all classes.

The Royal School of Mines is incorporated with the Royal College of Science. Students entering for the associateship of the School of Mines obtain their general scientific training in the Royal College of Science.

The associateship is granted in certain divisions or lines of study. Students who go through any one of these in the prescribed order, and pass the necessary examinations, receive a certificate of associateship of the Royal College of Science, or of the Royal School of Mines.

The associateship of the Royal School of Mines is given in one of the following divisions :—(1) metallurgy, or (2) mining.

The course of instruction, which lasts for three years, is the same for all the divisions during the first and second years (after which it is specialized) in accordance with the following scheme :—

First Year.—Chemistry, mathematics, physics, astronomical physics, and free-hand drawing.

Second Year.—Mechanics, machine drawing, elementary geology and mineralogy. Instruction is given in mathematics so far as may be necessary, and in descriptive geometry.

Metallurgy.

Third Year.—Metallurgy, assaying, and determinative mineralogy.

Mining.

Third Year.—Mining, metallurgy, assaying, determinative mineralogy, and mine surveying.

Examinations are held at the end of each course of instruction, and at such other periods as may be found necessary. On the results of these examinations the successful candidates who have attended regularly and otherwise conformed to the rules of the school are arranged in two classes, first and second.

There are also honours examinations for the subjects of the third year, the successful candidates being placed in order of merit. Honours are only obtainable by candidates for the associateship. No one will be allowed to attempt the honours examination who fails to obtain a first class in the ordinary examination. The candidate for honours will be required to pass an examination in some special branch or branches of one of the subjects in which the associateship can be taken. The papers set will be of a more advanced character than those in the ordinary associateship examination. The candidate will also be required to present a thesis on some special subject, and great weight will be given to the adequate description of any original work or research which has been carried out by the student in one of the laboratories of the school with the sanction of the professor. For the honours examination the subjects will be as follows, and the student will only be required to take up one of these:—

Division I.—Metallurgy.—Researches connected with the practical examination of a metallurgical process or details of a process, and theoretical metallurgy.

Division II.—Mining.—Description of some mine or mining district from personal study, with full details.

A student obtains the associateship who passes in all the subjects of the first two years, and in those of the special division which he selects for his associateship.

The obligation to go through the elementary, or first part in any of the foregoing courses, may be remitted in the case of any student who satisfies the council that he has received sufficient theoretical and practical instruction in those subjects.

The fees for the first two years amount to about £75, and for the remainder of the course for the associateship they vary from £30 to about £40. The private and State-aided students are required to furnish themselves with certain instruments and apparatus before the commencement of the courses.

No student will, except under very special circumstances, be entered for the associateship course unless he has passed in the first class of the elementary stage of mechanics, mathematics, chemistry, and physics, or in some higher stage of those subjects, at the May examinations of the department of Science and Art, or can show to the satisfaction of the council of the college, by having passed the examinations of other recognized examining bodies, that he possesses the necessary elementary knowledge of those subjects.

UNIVERSITY COLLEGE, BRISTOL.

The college supplies instruction in those branches of applied science which are more nearly connected with the arts and manufactures.

Civil Engineers or Surveyors.

The course of civil engineering has been arranged to extend over two years, but special arrangements will be made for students who may deem it advisable to remain for a third year.

First Year.—Physics, engineering, chemistry, mechanics, engineering and geometrical drawing, mathematics, and surveying.

Second Year.—Mathematics, engineering, physics, geology, engineering and geometrical drawing, bridge-construction, and surveying.

The compounded fee for the preceding course is, for each year, 28 guineas, and for second and third years 21 guineas, with a registration fee of £1 1s.

Mining Engineering.

Students who intend to become mining engineers follow the preceding course and special provision is made for their instruction in the third term of each year.

Any student who attends a course of instruction in any subject during a session, and obtains a place in the first or second class in the examination at the end of the course, is entitled to receive a certificate from the college.

An honours certificate is granted, after examination by an external examiner, in conjunction with the professor or lecturer on the subject, to any student of the college who has attended a course of instruction in any one of the subjects.

Associateships.

The title of associate of the University College, Bristol, is conferred on any candidate who (a) has attended an amount of instruction in the college equivalent to three courses of three hours per week each in each of three terms during two sessions; and (b) has obtained some one of the four following distinctions, namely:—(i.) College honours certificates in four subjects; (ii.) a certificate, granted by the examiners and approved by the council, of having produced an essay or original investigation of exceptional merit, together with honours certificates in three subjects; (iii.) a degree in any university in the United Kingdom; or (iv.) such distinction in the Oxford University examination for women, or the Cambridge University higher local examination, as from time to time shall be considered sufficient.

The title of associate in engineering is granted, on application, to all candidates who have complied with condition (a), and who obtain an honours certificate in engineering, and in three of the subjects, mathematics, physics, geology, or chemistry; provided that one at least of their certificates be in mathematics.

CAMBORNE SCHOOL OF MINES, CORNWALL.

The school is worked on the assumption that its students are for the most part engaged in the mines during the day. Instruction in the various scientific and technical subjects is therefore given mainly in the science school in evening classes; and only those subjects, such as assaying, surveying, etc., which demand more time

and are themselves of a practical character, are taught during the day. Facilities for working at the mines are afforded to students by the managers of some of the principal mines in the neighbourhood.

The school course extends over a period of three years, the subjects being arranged as set out below (in the case of a student working for a special course certificate, the arrangement of the subjects can be modified):—

First Year.—Freehand drawing, mathematics, geometry, chemistry, and physics. Machine-drawing, building-construction, or carpentry and joinery may be taken, if geometry is one of the subjects chosen.

Second Year.—Machine-drawing, mineralogy, building-construction, geology, hydrostatics, dynamics, applied mechanics, and mining.

Third Year.—Advanced stages of the foregoing subjects, together with steam, ore-dressing, and metallurgy.

Special Course Certificates.

The special course certificates are of three kinds: mining, mechanical, and chemical. The certificates are of two classes. The qualifications specified below give the minimum required for a pass. To obtain the higher certificate more advanced stages of these subjects count; and such other certificates as the applicant may send in will be considered on their merits. To qualify for a certificate in any course, passes in at least four of the following subjects must be obtained:—Mathematics, geometry, hydrostatics, dynamics, physics, and chemistry. But a certificate of matriculation at any of the universities will be held equivalent.

Mining Course Certificate.

To obtain a mining course certificate, in addition to the preceding, the student must produce a certificate of having worked underground as a miner for at least twelve months; and pass mining (first class advanced stage), ore-dressing (honours stage), and a practical examination in surveying, blowpipe analysis and assaying.

THE DURHAM COLLEGE OF SCIENCE, NEWCASTLE-UPON-TYNE.

This college represents the faculties of science and engineering in the University of Durham, and thus fulfils the functions of a University College in the North of England.

Complete courses of instruction are provided for mining engineers, mechanical engineers, marine engineers, naval architects, electrical engineers, metallurgists, and chemical manufacturers.

Associateship in Physical Science.

Every candidate for the associateship in physical science will be required to satisfy the examiners in mathematics, physics, chemistry, and either geology, natural history, or biology in an examination to be held at the end of the candidate's first year. At the end of the second year, every candidate must pass an examination in the higher parts of two of the subjects, in the elementary parts of which the candidate passed an examination at the end of the first year.

Associates in science are admissible one year after obtaining the title of associate, having some time before or during their college course passed the examination in the examination for the degree of bachelor of science of the

Mechanical, Mining, or Civil Engineer.

Associates in physical science, who, after their admission to this rank, have been engaged for three years at least in some practical work of mechanical, mining, or civil engineering approved by the council, and have subsequently passed a further examination, having, principally, reference to the work in which they have been engaged, shall be admissible, by grace, to the title of mechanical, mining, or civil engineer of the University of Durham.

The following courses of study are recommended :—

Associateship in Science.

First Year.—Mathematics, physics, practical physics, chemistry, practical chemistry, and either geology, biology, or natural history.

Second Year.—Any two of the following subjects :—Mathematics, physics, chemistry, geology, biology, or agriculture.

Metallurgy.

First Year.—Mathematics, physics, chemistry, mechanical drawing, German or French, and physical and chemical laboratories.

Second Year.—Chemistry, metallurgy, geology, mechanical drawing, German or French, and chemical and metallurgical laboratories.

Third Year.—Metallurgy, chemistry, geology, engineering, and chemical and metallurgical laboratories.

Mining.

First Year.—Mathematics, physics, chemistry, geology, mechanical drawing, and chemical and physical laboratories.

Second Year.—Mathematics, mechanical engineering, mechanical drawing, surveying, coal and metalliferous mining, and technical electricity.

Third Year.—Students able to devote a third year to their studies should attend a special course on chemistry, mechanical and electrical engineering, and the engineering laboratory.

Degrees in Engineering.

Students who intend to proceed to a degree in engineering are recommended to pursue the following course of study. The degree of B.Sc. in engineering may be taken in any one of the four following branches of engineering :—(a) Mechanical engineering and naval architecture ; (b) electrical engineering (including mechanical engineering) ; (c) mining ; and (d) civil engineering.

Mining (including Mechanical Engineering).

The course of study (extending over three years) recommended for those who intend to proceed to the degree of B.Sc. in mining is :—

First Year.—Mathematics, physics, chemistry, geology, biology, natural history, and physical and chemical laboratories.

Second Year.—Mathematics, physics (including technical electricity), engineering, mechanical drawing, and physical and engineering laboratories.

Third Year.—Mathematics, physics (including technical electricity), mining, mechanical drawing, and physical, mining, and engineering laboratories.

This course may be extended over four years in cases where the student is unable to undertake it in three years.

The titles and degrees of the University of Durham in science and engineering are open to evening students who pass the matriculation examination, attend

regularly for not less than ten hours per week (in the evenings or on Saturdays), and pass the same examinations as the day students. Evening students may present themselves for the first examination for the associateship in science at the end of their second session, and for the final examination for associateship at the end of their third session, if they obtain a first class in the first examination, otherwise they may present themselves at the end of their fourth session. Evening students continuing to attend the classes for ten hours weekly may present themselves for the examination for B.Sc. one year after obtaining the associateship.

SHEFFIELD TECHNICAL SCHOOL, SHEFFIELD.

The work of the institution is divided into three departments :—(1) The junior day department. (2) The senior day department :—(a) Engineering section ; and (b) metallurgical section. (3) The evening department consisting, amongst others, of special sections of engineering, metallurgy, mining, and building.

Mechanical Engineering.

The course of study is designed to meet the requirements of mechanical, electrical, or mining engineers, architects, or others engaged in industries where a knowledge of mechanical principles is of importance. The complete course extends over three years, and includes attendance at lectures and classes, experimental work in the laboratories, and practical work in the workshops and drawing office.

The prescribed subjects for the complete course are given below :—

First Year.—Mathematics, applied mechanics, engineering laboratory, physics, machine drawing and geometry, engineering, and workshops. The composition fee is £16 16s.

Second Year.—Mathematics, mechanics, physics, machine drawing and design, engineering, engineering laboratories, and workshops. The composition fee is £17 17s.

Third Year.—The following general course of study may be varied according to the special requirements of each individual student. It consists of mathematics, iron and steel, fuel, machine drawing and design, engineering and electrical laboratories, and workshops. The composition fee is £18 18s.

Mining Engineering.

Students of mining engineering take the subjects of the mechanical engineering course, together with special courses in chemistry and geology, for the first year, and mine surveying, the theory and practice of coal-mining, and practical fuel analysis, for the second year.

Metallurgical Engineering.

The prescribed subjects are given below :—

First Year.—Mathematics, physics, chemistry, iron and steel, machine-drawing, and metallurgical laboratory. The composition fee is £18 18s.

Second Year.—Fuel and refractory materials, mathematics, physics, chemistry, machine-drawing, and metallurgical laboratory. The composition fee is £18 18s.

Third Year.—Geology, mineralogy, mathematics, applied mechanics, machine-drawing, and metallurgical laboratory. The composition fee is £18 18s.

Associateship of the Sheffield Technical School.

The associateship of the school is awarded in engineering or metallurgy to each student who attends the lectures and laboratory work prescribed for the complete three years' day courses, and passes the annual examinations satisfactorily in each of the subjects.

THE YORKSHIRE COLLEGE, LEEDS.

The Yorkshire College is intended to promote the education of persons of both sexes, and in particular to provide instruction in such sciences and arts as are applicable to the manufacturing, mining, engineering, and agricultural industries of the county of York, and in ancient and modern languages, history and literature, medicine, surgery, law, logic, moral philosophy, and any other subjects of university or college teaching.

The Yorkshire College is one of the colleges of the Victoria University, and has power to confer degrees on persons who have pursued a regular course of study, and who submit themselves for examination.

Coal-mining (maintained by the Drapers' Company of the City of London).

The coal-mining course occupies two years, and includes courses of lectures on mining engineering, surveying, chemistry, and geology.

First Year.—The lectures include the chemistry and geology of coal-mining, theory and practice of coal-mining, mining engineering, and colliery management.

Second Year.—The lectures comprise the theory and practice of coal-mining, mining engineering, colliery management, and underground surveying.

SYDNEY TECHNICAL COLLEGE, ULTIMO, NEW SOUTH WALES.

The technical education branch of the department of public instruction, New South Wales, comprises about forty technical schools situated at various centres, and the technical college at Ultimo.

The following are the departments of instruction:—Agriculture, architecture, art, chemistry, commerce, domestic economy, industrial and decorative arts, geology, mineralogy, mining, mathematics, mechanical engineering, sanitary engineering, electrical engineering, pharmacy, physics, sheep and wool training, printing, and classes in tailors' cutting, scientific dresscutting, dressmaking, and ambulance surgery.

Mining and Mining Engineering.

This department provides separate courses of lectures and laboratory instruction in each of the following branches of mining engineering:—Coal-mining, metalliferous mining, mine-surveying, and mining machinery.

For a diploma in either branch of mining engineering, students must attend all the classes and pass the prescribed examinations.

The course for the diploma is as follows:—Coal-mining or metal-mining, mine-surveying, mining engineering, geology and mineralogy, and workshops.

Certificates are awarded to students who attend the classes and pass the required examination at the end of the course.

Diplomas will be awarded to students who have attended a complete course of instruction in any department of science or art, and have satisfactorily passed the prescribed examinations. Students who pass their final examination with the highest order of merit receive a diploma in honours.

A diploma in honours entitles students to the distinction of associate of the Sydney Technical College.

The fellowship of the Sydney Technical College will be conferred upon those who, having obtained the associateship, shall have spent not less than six years in actual practice and shall have done some original and valuable research work, or have contributed to the advancement of the industry in which they are engaged.

UNIVERSITY OF OTAGO, DUNEDIN, NEW ZEALAND.

The university contains faculties of arts, science, medicine, and law; and a school of mines.

SCHOOL OF MINES.

The school of mines was established in 1878. It comprises classes in mining, mining geology, mineralogy, and petrography, mathematics, theoretical and applied mechanics, physics, palæontology, theoretical and technological chemistry, qualitative and quantitative analysis, metallurgy, assaying, general geology, and surveying.

There are four divisions—mining, metallurgical, geological, and mine-surveying. In the first three divisions the course of study can be completed in three years, and in the fourth division in two years.

Students who pass the examinations in any of the first three divisions obtain the distinction, with diploma, of associate of the University School of Mines, Otago. On passing successfully the examinations in the fourth division they are entitled to receive the certificate of mining surveyor.

The following are the courses of study prescribed for the respective divisions :—

Associateship.—Mining Division.

First Year.—Mathematics, general geology, mining geology, theoretical chemistry and chemical technology, applied mechanics, mine and land-surveying, and drawing.

Second Year.—Theoretical mechanics, physics, mineralogy, use of the blowpipe and determinative mineralogy, mining, applied mechanics, mine and land-surveying, drawing, and ore-dressing.

Third Year.—Physics, petrography, mining, mechanical gold-extraction, chemical and metallurgical laboratories, assaying and metallurgy, and drawing.

Associateship.—Metallurgical Division.

First Year.—Mathematics, general geology, mining geology, theoretical chemistry and chemical technology, applied mechanics, and drawing.

Second Year.—Theoretical mechanics, physics, mineralogy, use of the blowpipe and determinative mineralogy, metallurgy (including ore-dressing), applied mechanics, drawing, and chemical laboratory.

Third Year.—Physics, metallurgy, mechanical extraction of gold, assaying and metallurgy, drawing, and physical and metallurgical laboratories.

Associateship.—Geological Division.

First Year.—Mathematics, general geology, mining geology, theoretical chemistry and chemical technology, mine and land-surveying, and drawing.

Second Year.—Physics, mineralogy, use of the blowpipe and determinative mineralogy, mine and land-surveying, surveying practice, biology, drawing, and biological laboratory.

Third Year.—Theoretical mechanics, physics, petrography, palæontology, drawing, geological field practice, and physical and chemical laboratories.

Mining Surveyor's Course and Certificate.

First Year.—Mathematics, general geology, mining geology, theoretical chemistry and chemical technology, mine and land-surveying, and drawing.

Second Year.—Theoretical mechanics, physics, mineralogy, use of the blowpipe and determinative mineralogy, mine and land-surveying, surveying practice, drawing, and physical laboratory.

UNIVERSITY OF KING'S COLLEGE, WINDSOR, NOVA SCOTIA.

The King's College University confers degrees in arts, divinity, law, engineering and science.

The aggregate outlay necessary, for the three years' residence and study qualifying for a degree, may be estimated at about £30 to £40 per year. The mere money payment demanded need never, however, exclude a candidate really prepared to benefit by the course of instruction offered, inasmuch as many benefactors of the university possess the right of nomination. Each nominee is exempt from the payment of certain yearly fees besides the fee for a B.A. degree. There being some forty certificates conferring this privilege, it is easy for students to obtain it. If a scholarship is held besides, nearly the whole cost of education will be covered.

There are at present in the university five schools open to matriculated students of arts, divinity, engineering, science, and civil law.

The course of engineering is framed with the view of giving the student a sound and thorough training in mathematics, pure and applied, a comprehensive knowledge of engineering and applied science, together with such practical experience in work connected with the profession of a civil engineer as it is within the scope of the university to afford.

The course for B.Sc. has been established for carrying on advanced study in mining and chemistry.

Degree of Bachelor of Engineering.

Undergraduates presenting themselves for examination for the degree of bachelor of engineering shall be required to have been duly matriculated in the school of engineering; to have subsequently studied in King's College the course herein prescribed, and to have passed the first university examination for the said degree.

The course for the degree in civil or mining engineering shall usually extend over four years, and shall comprise attendance on the following curriculum:—

First Year.—Mathematics, chemistry, French or German, English literature, surveying and levelling, and field and office work.

Second Year.—Mathematics, analytical chemistry, chemical physics, botany and zoology, French or German, English literature, mensuration, surveying and levelling, office work, and engineering excursions.

Third Year.—Mathematics, mathematical physics, geology, mineralogy (including blowpipe analysis), civil engineering, applied mechanics, geometrical drawing, engineering office and field-work, and geological excursions.

Fourth Year.—Natural philosophy, mathematical physics, civil engineering, and engineering office and field work.

Degree of Master of Engineering.

Every candidate for the degree of master of engineering must have taken the degree of bachelor of engineering, and must have been engaged in practical work connected with the profession of a civil engineer for at least three years from the time of so doing. He must have held a position of responsibility in such connexion.

He will be examined in each of the following groups of subjects:—(1) Practical engineering: the preparation of designs, specifications and estimates for civil engineering work. (2) Applied science: (a) applied mathematics; (b) technological chemistry, assaying and analysis; (c) geology and mining; (d) practical electricity. Candidates must select one of the four subjects in the second group. The particular department of engineering work in which the candidate is examined will be chosen with reference to the character of the work in which he has been specially engaged, and in this portion of the examination candidates will be tested as regards

their knowledge of the subject by being required to submit a complete set of drawings, specifications, and estimates for some proposed work, for the preparation of which a month or five weeks will be allowed. These drawings, with the detailed calculations upon which they are based, will be sent in to the examiners, and if they are approved an oral examination of the candidates will be conducted for the purpose of verifying the authenticity of the work submitted, and of testing the candidate's professional ability.

Degree of Bachelor of Science.

The course of study comprises :—

First Year.—Mathematics, chemistry, English literature, French or German, surveying and levelling (with field and office-work).

Second Year.—Mathematics, chemistry, qualitative analysis, chemical physics, botany, zoology, English literature, French or German, mensuration, surveying, and levelling (with office-work).

Third Year.—Mathematical physics (mechanics and hydrostatics), geology (including petrography and field geology), mineralogy (including crystallography and blowpipe analysis), mining, economics, geometrical drawing, French or German, and geological excursions.

Fourth Year.—Mathematical physics (optics and astronomy), economic geology and mineralogy, chemistry (quantitative analysis of minerals, ores, etc.), metallurgy and assaying, geological drawing, economics, and French or German.

Degree of Master of Science.

Candidates for this degree must be B.Sc.'s of three years' standing. Every candidate will be required to send in a thesis on some scientific subject embodying original work, and also, in addition, be required to pass an examination on one of three or more subjects to be named in the calendar :—Coal, iron, and copper (in each case with analysis and methods of mining).

Degree of Doctor of Science.

Candidates for D.Sc. must be B.Sc.'s of eight years' standing or M.Sc.'s of five years' standing. A thesis on some approved subject to be sent to the board of examiners, and a proof of continued successful work in science.

BALLARAT SCHOOL OF MINES, INDUSTRIES AND SCIENCE,
UNIVERSITY OF MELBOURNE, BALLARAT, GRENVILLE COUNTY,
VICTORIA.

This school was established for the purpose of imparting instruction in the various branches of science relating to mining, the theory and practice thereof included.

There are six courses of study, viz. :—Mining, metallurgy, geology, agriculture, electrical engineering, and civil engineering. In each of these the associateship of the School of Mines can be obtained.

Mining Engineering Course.

First Year.—Mathematics, natural philosophy (mechanics and heat), land surveying, mechanical drawing, mineralogy, geology, and theoretical chemistry.

Second Year.—Mathematics, natural philosophy (sound, light, electricity and magnetism), land-surveying, mechanics (theoretical and applied), mechanical drawing, mineralogy, petrography, geology, analytical chemistry (qualitative), chemical laboratory practice, and metallurgy.

Third Year.—Mathematics, applied electricity, mechanics (theoretical and applied), mine-surveying, mechanics as applied to mining, mechanical drawing, scientific mining, geological surveying, analytical chemistry (quantitative), and assaying.

In order that a student may receive his certificate of associateship in the mining engineering course he must produce satisfactory documentary evidence that he has served for at least one year under a duly qualified mining engineer, mining surveyor, or mine manager.

Metallurgy Course.

First Year.—Natural philosophy (mechanics and heat), mathematics, mechanical drawing, mineralogy, geology, theoretical chemistry, analytical chemistry (qualitative), and chemical laboratory practice.

Second Year.—Natural philosophy (sound, light, electricity and magnetism), mathematics, mechanics (theoretical and applied), mineralogy, petrography, geology, theoretical chemistry, analytical chemistry (quantitative), chemical laboratory practice, metallurgy, and assaying.

Third Year.—Applied electricity, mineralogy, petrography, chemical geology, analytical chemistry (quantitative), chemical laboratory practice, metallurgy, assaying, and mining laboratory-work (ore-dressing, etc.)

Manager's Course.

The curriculum for mine managers is divided into three parts, comprising:—1) Practical mining, including elementary geology; (2) mine surveying, including plotting and computing; (3) mechanics, as applied to mining, including strength of materials, drainage, ventilation, explosives.

The school's certificate of competency as a mine manager is awarded to each candidate who has passed in all the subjects prescribed. He must also produce satisfactory evidence of having worked underground at least two years in a mine in which not less than fifty men were employed, and in which the operations were carried on by steam-power and machinery. A candidate having had two years' experience as a quartz miner must produce satisfactory evidence of having been employed at least twelve months in an alluvial mine to entitle him to a certificate as a mining manager of alluvial mines.

Intending students are recommended to take a preliminary course of instruction in the following subjects taught in the miners' class, viz.:—Arithmetic, logarithms, elementary trigonometry, mensuration, and Euclid (optional).

SCHOOL OF MINES AND INDUSTRIES, BENDIGO, VICTORIA.

The School of Mines and Industries, Bendigo, was established for the following purposes:—(a) To impart sound instruction, chiefly in the various branches of science connected with mining operations, and to instruct students in the theory and practice of mining, in geology, mineralogy, physical geography, meteorology, and in physical, natural, and applied science; (b) to thoroughly teach chemistry, metallurgy, and assaying; (c) arithmetic, algebra, mathematics, surveying, and

astronomy; (d) drawing and painting in their various branches, lithography, wood engraving, and the theory and practice of the mechanical trades, modelling and carving; (e) ancient and modern languages; (f) shorthand writing, telegraphy, and allied subjects; and (g) such other subjects as may from time to time be deemed desirable by the council.

The lectures comprise classes in geology and mineralogy, chemistry and metallurgy, practical mining, engineering and surveying, botany, zoology, architectural and geometrical drawing, machine and building construction, drawing and painting in all its branches, telegraphy, shorthand, the French, German, Latin, and Italian languages, and elocution.

Examinations are held and certificates granted at the end of each course of lectures.

ROYAL SCHOOL OF MINES, PŘŽBRAM, BOHEMIA.

The Royal School of Mines embraces a school of mining and a school of metallurgy, either of which can be passed through in one year.

The school of mining comprises lectures on mining, geology of ore-deposits, ore-dressing, mine-surveying, surveying and plotting, theory of mining machines, building-construction, and chemical analysis.

The school of metallurgy comprises lectures on the metallurgy of iron, general metallurgy, manufacture of salt, assaying, assays and analyses, and theory of smelting.

There are also lectures on building-construction, forestry, mining law, book-keeping, metallurgy, mining (in brief), and first aid to injured.

Any ordinary student who has gone through either or both of the two schools can obtain certificates of the results of the examinations.

At the end of each term examinations are held in those subjects the lectures on which have terminated in that term.

HAINAUT SCHOOL OF MINES AND INDUSTRY, MONS, BELGIUM.

The Hainaut School of Mines course extends over four years, at the end of which the diploma of engineer is given to successful students. Candidates of all nationalities are admitted.

The tuition fee is under £5 per annum, but books, apparatus, etc., are not provided by the school.

Diplomas are awarded after courses of instruction in mining, metallurgy, applied chemistry, mechanical engineering, railway engineering, building construction, and electricity.

At the beginning of the fourth year students must decide which of the subjects they intend to take up for their diploma, but it is possible to obtain a diploma in two subjects in the four years. It is impossible to tell from the college programme what is exactly the mining course. It appears, however, that the first two years are devoted to general science and engineering, and the last two years to mining and more advanced portions of the first year's subjects.

**SCHOOL OF ARTS, MANUFACTURES, AND MINES, ATTACHED TO
THE UNIVERSITY OF LIÉGE, LIÉGE, BELGIUM.**

The object of this school is to qualify students for the degree of engineer. It has two divisions, viz., the preparatory and the special school. The preparatory school prepares students for the special school.

The special school is divided into four sections :—Mining, mechanical engineering, electrical engineering, and arts and manufactures. In each of these the degree of engineer can be obtained. The mining division requires a five years' course, including the two years in the preparatory school; each of the other divisions four years, including two years in the preparatory school.

According to Belgian law no one can hold a government appointment as engineer unless he has obtained the degree of engineer. Candidates are examined in the same subjects as those for entrance into the preparatory school, and in the work done during the two years' course in this school. Foreigners may be examined in Latin, or in their native language instead of in French. The fees appear to be about £6 a year.

The course of study in the mining division is as follows :—

First Year.—Grammar, analytical geometry of three dimensions, descriptive geometry, experimental physics, French composition, drawing, and geometrical drawing.

Second Year.—Descriptive geometry, applied and analytical mechanics, elements of astronomy and geodesy, general chemistry, English or German, drawing, and applied geometrical drawing.

Third Year.—Applied mechanics, industrial physics, machine description, mineralogy, assaying, English or German, etc.

Fourth Year.—Geology, working of mines, industrial and inorganic chemistry, metallurgy, industrial architecture, applications of electricity, English or German, etc.

Fifth Year.—Mining, topography, railway working, industrial architecture, metallurgy, industrial geography, industrial economy, law of mines and industries, English or German, etc.

The course also includes visits to mines, works, etc., and geological excursions. There are similar courses leading up to the other engineering degrees. The candidates for degrees may sit for their final examination at the end of each year.

CATHOLIC UNIVERSITY OF LOUVAIN, LOUVAIN, BELGIUM.

The schools, annexed to the Catholic University of Louvain, train engineers for every branch of industry. They grant the following diplomas, viz. :—(a) Civil engineer of mines; (b) engineer of building-construction; (c) engineer of arts and manufactures, and of mines; (d) engineer-constructor; (e) engineer-architect; and (f) conductor of building-construction. (a) and (b) are obtained after a five years' course; (c), (d), and (e) after a four years' course; and (f) after two years. A course consists of at least 200 hours of study in each year.

The course of instruction includes excursions and reports, the students visiting coal-mines of the various Belgian basins, metallurgical establishments, engineering-works, etc.

The fees amount to about £10 a year, and in addition there are examination fees varying in amount from £1 5s. to about £3.

THE NATIONAL HIGHER SCHOOL OF MINES, PARIS, FRANCE.

The National School of Mines was founded in the first instance to train engineers for the mining corps. Of late years its doors have been opened to others, both natives and foreigners, anxious to obtain an industrial training. There are no fees for instruction.

There are three classes of students, viz.:—(1) Engineer students. These come from the Polytechnique, and are intended for the service of the State. (2) Day students. These enter the school by competitive examination. (3) Foreign students. These are admitted, after passing a qualifying examination, on the recommendation of the ambassadors or *chargés d'affaires* of foreign powers. They are not compelled to follow the complete course, but can select at the beginning of the year the line of study which they wish to pursue, and in this only will they be examined, and will receive a certificate. There is also a fourth class of students known as free students. These are either natives or foreigners authorized by the Minister of Public Works to follow the whole or a part of the course. They do not attend the practical work, or the examinations, nor do they receive a diploma.

The length of the special course of study is three years; and in addition there is the preparatory course of one year.

The training at the School of Mines is especially directed to imparting a knowledge of all matters relating to minerals. But, besides this, instruction is given on the general conditions of modern industry, machines, railways, building construction, legislation, and economics.

A course of military art is provided for those students holding a place in the army; and, lastly, German and English are taught, to enable the students to study the scientific works written in those languages.

The courses of instruction are as follows:—

Preparatory Year.—Mechanics, analysis and descriptive geometry, physics, chemistry, drawing, and preparations for the examinations.

Special Course.

First Year.—Working of mines, metallurgy, analytical chemistry, industrial chemistry, mineralogy, palæontology, topography, German and English, drawing, mining and metallurgical designs, mineral analysis, and preparation for the examinations.

Second Year.—Metallurgy, analytical chemistry, geology and petrography, machines and strength of materials, railways, economics, German or English, metallurgical and machine design, mineral analysis, industrial and geological excursions, and preparation for the examinations.

Third Year.—Applied geology, building and machine-construction, legislation, applications of electricity, artillery, German or English, and preparation for the examinations.

DOUAI MINE-OVERMEN'S SCHOOL, DOUAI, FRANCE.

The object of this school is to train workmen for the position of overmen, etc. The students are boarded at the school, paying about £20 a year. The length of the course is two years, half of which is spent in a mine. The students are taught grammar, arithmetic, elementary geometry, so much trigonometry and geometry as is required for surveying, physics and chemistry, etc. Diplomas are given at the end of the course.

Candidates must be at least sixteen years old, and have worked in a mine. They must also pass an examination in reading, writing, and arithmetic.

SAINT ETIENNE SCHOOL OF MINES, SAINT ETIENNE, LOIRE,
FRANCE.

The object of the school is to train engineers, managers of mines, and managers of metallurgical works. The instruction is free, and extends over a period of three years. The first year is devoted to pure mathematics, mechanics, physics, mineral analysis, mineralogy, descriptive geometry, stereotomy, and planning. The two other years to practical work:—Working of mines, washing and dressing of minerals, machines and buildings, metallurgy, mineral analysis, geology, railways, law of mines, vegetable palæontology, and book-keeping. The students visit the neighbouring mines.

Diplomas and certificates are given to those who have satisfactorily gone through the course of study. Foreigners are admitted, after having passed an examination to show that they are capable of following the course of instruction.

Candidates for admission must be Frenchmen or naturalized Frenchmen (though foreigners are also admitted) between 17 and 26 years of age, and must pass an entrance examination. The students are not boarded. The cost of board and lodging is about £1 a week. The cost of the uniform is about £8.

BERLIN ROYAL GEOLOGICAL AND MINING INSTITUTE, BERLIN,
GERMANY.

The geological department is for making maps, etc., of the geological formations of the German empire.

The mining department for teaching students the theoretical and practical parts of mining, metallurgy, surveying, etc. The following subjects are taught in the mining department:—Mining, metallurgy, metallurgy of iron, assaying, blowpipe analysis, technical chemistry, land and mine surveying, machine construction, designing chemical works, building construction, mechanical drawing, trigonometry, analytical geometry, differential and integral calculus, mechanics, mineralogy, petrology, geognosy, palæontology, analytical chemistry, mining law, etc.

The whole course takes three years, the latter part of which is spent in practical work. German students are admitted on producing certificates of attendance at any German technical school or college. Students can go up for examination in any subject they choose, and will be given certificates—provided they satisfy the examiners.

ROYAL TECHNICAL COLLEGE, AIX-LA-CHAPELLE, GERMANY.

The Technical College aims at affording education for a technical calling in the Government or civil service and in commercial life.

The Technical College is under the supervision of the Government Minister for Education, and consists of the following departments:—(1) Architecture; (2) civil engineering; (3) mechanical engineering; (4) mining, metallurgy, and chemistry; (5) general sciences, especially for mathematics and natural philosophy.

The lectures are arranged in yearly courses. Only in exceptional cases does a course of lectures extend over part of a year only.

The admission of a German to the college is dependent on his producing a leaving certificate from a German public school or commercial college. A foreigner can be admitted into the college if the warden and director of the department, which he wishes to enter, are satisfied that he is qualified for the same by age, education, etc.

On joining the college each student receives a certificate of admission which is available for four years, but which can be prolonged if required.

Examinations are held in the case of one year lectures, at the end of the college year; and in the case of the half-year lectures, at the end of each half-year. Students may enter for final examination in those subjects, the lectures on which they have attended, and receive certificates for the same.

Students who have followed the four years' course of instruction in any of the departments are entitled to enter for a diploma examination, and receive a diploma testifying to their acquirements and practical knowledge, and entitling them, as the case may be, to the degree of (a) architect; (b) metallurgical chemist; (c) civil engineer; (d) metallurgical engineer; (e) mechanical engineer; (f) surveyor; (g) electrical engineer; (h) mining engineer. These examinations take place in two parts, the preliminary at the end of the second year, and a principal examination on the completion of the course.

The appointment as an official in the Government Architectural Service is obtained by passing a preliminary and two principal examinations, these, according to the branch which they concern, being divided into:—(a) Building; (b) civil engineering; (c) mechanical engineering.

For the mining department of the Government Service there are special rules and regulations. The course of instruction is as follows:—

Mining, Metallurgy, and Chemistry.

The course includes:—Mineralogy and crystallography, with practical exercises in determination of minerals; petrography, practice in the mineral collection; guidance to independent crystallographical, mineralogical, and petrographical work; experimental inorganic chemistry, chemistry of benzol and pyridin, practical chemistry, general and inorganic experimental chemistry; introduction to metallurgical experiments, mining, ore-dressing, salt-mining, chemistry of the metals, volumetric analysis, historical chemistry; introduction to metallurgy, metallurgy of iron, general metallurgy, iron casting, new methods of extracting metals, electro-metallurgy, etc., designing of smelting-works, metallurgical assaying, blowpipe analysis; designing of mining and ore-dressing works, mining law, mine management; technical chemistry, designing of chemical works, practical technical chemistry; land and mine surveying, drawing, practical land and mine surveying, physical geography, ore-deposits, palæontology, structural geology, practical palæontology, elements of mineralogy and geology.

ROYAL SCHOOL OF MINES, CLAUSTHAL, HARZ, GERMANY.

The college is devoted to teaching mining and metallurgy. Students are of two grades: "bergakademiker" and "hospitanten."

The standard of the qualification for admission as a "bergakademiker," in the case of Germans, is the final certificate of a gymnasium, high school of the first class or one of the Royal Prussian Trade Schools. Foreigners have to give proof by means of certificates of equivalent education.

Students with less previous education can be admitted as "hospitanten," provided that their certificates prove that they have had sufficient education to enable them to fully understand the lectures. At the end of a year "hospitanten" who are qualified, have the opportunity of becoming "bergakademiker" if they can pass an entrance examination in a full course of elementary mathematics.

The course of instruction is divided into the practical preparatory course and the ordinary course of lectures.

The practical preparatory course begins every year in the first week after Easter, and is devoted to mining, ore-dressing, and smelting. The fee for each of the branches is 18s.

Students are examined in any of the single subjects, or in all the mining and smelting subjects, for which degrees are given. Examinations are held at the end of each term and a certificate will be given by the director of the academy to students passing examinations in any of the subjects taught.

Mining or Metallurgical Engineer's Certificate.

Students who wish to obtain a degree of mining or metallurgical engineering must, at the end of the first year, pass an intermediate examination, and can take either or both parts.

The cost of board and lodging is from £4 to £6 per month, and the total cost of fees, board, and lodging, would be from £50 to £70 for the college year.

The following course of lectures in the mining department, for students who have attended a technical college before, is recommended to students, but they are free to take any lectures they choose. The director will always advise students on the above point.

First Year.—Trigonometry, algebra, analytical plane-geometry, differential and integral calculus, descriptive geometry, physics, mechanical drawing, chemistry, palæontology, ambulance lectures, general jurisprudence and mining law, analytical solid geometry, and lectures on the commercial part of mining.

Second Year.—Mineralogy, practical mineralogy, mechanics, mining, surveying, geology, qualitative chemical analysis, blowpipe analysis, theory of combustibles, ore-dressing, mining geology, practical physics, and qualitative chemical analysis.

Third Year.—Machine-construction and designing, assaying, mining law, mineral deposits, geotectonic or structural geology, electricity, building construction, blowpipe analysis, and qualitative analysis.

THE ROYAL SAXON ACADEMY OF MINING, FREIBERG, SAXONY.

This school is intended to prepare students for the professions of mining and metallurgical engineers and surveyors. Training for other professions is not given, neither does the curriculum include general education.

Applicants who are not subjects of the German empire may be exempted from the matriculation examination, if they are provided with certificates admitting them to institutions of the same standing in their own land.

Partial exemption from the matriculation examination may be permitted to applicants of mature years who substitute experience in practical work for deficiencies in theoretical knowledge, and to those who can furnish evidence of efficiency in arts instead of science.

The object of the practical course in mining is the acquirement of such information as is desirable for a course of study in mining engineering.

The work of the practical course at the Freiberg mines must be taken as follows:—1. Surface work for eight or nine weeks in ore-dressing and concentration. 2. The time remaining is to be spent in work underground, and also in visiting under the direction of the professor of mining engineering other mines in the district.

The fees for tuition appear to amount to about £10 a year for natives and £15 a year for foreigners ; but the programme is not very distinct upon this point.

The full course in mining extends over a period of four years :—

First Year.—Mathematics, descriptive geometry, spherical trigonometry, physics, inorganic chemistry, mineralogy, crystallography, drawing, and planning.

Second Year.—The higher parts of some of the above subjects, mechanics, mining, geology, palæontology, economic geology, blowpipe analysis, and mechanical drawing.

Third Year.—Surveying, mining, engineering, metallurgy, building construction, and machine-drawing.

Fourth Year.—Surveying, general and mining law, mining and metallurgical buildings, calculations and statistics, political economy, sanitation, and technical electricity.

At the close of the course the student sits for a final examination, and, in the event of passing, obtains a diploma.

HALLE AND ANHALT MINING SCHOOL, EISLEBEN, SAXONY.

The school is divided into two departments, the former being preparatory for the latter. There are four preparatory schools situated in various parts of Saxony, and the higher school is situated at Eisleben.

The object of these schools is to train officials for the mines and works of the Halle district. As, however, foreigners are not admitted it is unnecessary to give here an abstract of the educational course.

STOCKHOLM POLYTECHNIC SCHOOL, STOCKHOLM, SWEDEN.

The Mining College at Stockholm forms a part of the Polytechnic School, and includes courses of either three or four years, of which the last only is entirely devoted to the science of mining.

During the first year instruction is given in mathematics, mechanics (theoretical and practical), the construction of machines, physics (general and applied), chemistry, architecture, geology and mineralogy, geodesy, geometry, constructive drawing and freehand.

The last year is occupied with the study of metallurgy, working of mines and testing of ore and docimacy, and mechanics. The pupils pass great part of the summer in visiting mines and ironworks.

Hitherto the instruction has been gratuitous, but hereafter a small fee will be required. The pupils who have passed through a complete course obtain certificates of capacity.

TOKIO COLLEGE OF ENGINEERING, TOKIO, JAPAN.

The College of Engineering forms one branch of the University of Tokio. The students enter after a six years' course in a preparatory school, where there are from 1,200 to 1,500 boys. There they improve their English, French, and German ; learn all mathematics required by engineers, including the calculus, have some forty lectures in geology, and mineralogy, and considerable laboratory practice. Formerly about forty of these, but now about ninety, go every year into the engineering

college, and others to the medical, law, literature, and pure science branches of the university. The geology taught in the engineering college is purely technical.

The mining course should consist of one hundred and twenty lectures, but sickness, typhoons, earthquakes, etc., usually reduce it to about one hundred. One year a typhoon stopped the classes for a week, and last year an earthquake stopped them for nearly three weeks.

All lectures are given in English. Much of the designing work goes into practice, the rest into models for the museums, which are now said to be better than anything of the kind in Europe, America, and Australia. There is a large workshop always running, with a variety of motors (steam, electric, gas, and water), a metallurgical laboratory, and a fair number of dressing-machines.

The summer vacations are spent at mines, and all the students who have passed through the college find employment in Japan, China, Corea, etc.

The mining course extends over three years, and is as follows:—

First Year.—Mining, mineralogy, geology, steam engine, mechanism, building-construction, surveying, determination of minerals, qualitative analysis, designing, and metallurgy.

Second Year.—Underground surveying, metallurgy, ore-dressing, water motors, pumps, cranes, etc., determination of minerals, assaying, blowpipe analysis, and quantitative analysis.

Third Year.—Mining, metallurgy, ore-deposits, mechanical and metallurgical technology, metallurgical experiments, mechanical engineering, mining designing, metallurgical designing, and mining law.

Adjoining the main college building is a dormitory, where the students of the college reside.

UNIVERSITY OF ARIZONA, TUCSON, ARIZONA, UNITED STATES.

The departments of instruction are:—(1) Science, literature, and the arts; (2) teachers' training, and elementary instruction; (3) agriculture; (4) normal department; and (5) mineralogy and the school of mines. The third and fifth departments were established as the beginning of the university. The fourth department is provided for by legislative enactment in the popular and well-managed Territorial Normal School at Tempe. The first and second departments will be established when the income of the university will permit.

The tuition is free. Matriculation fee, to be paid but once, £1. Students are charged for material used in laboratories. A dormitory for the accommodation of a limited number of students has been fitted up in the university building, to be used until the students' dormitory is built, where students will be boarded at cost price, which will not exceed £4 per month. Books cost from £1 to £2 per year.

THE SCHOOL OF MINES.

This college of the university subserves a twofold object, firstly, the thorough training of young men in the sciences of mining and metallurgy to such an extent as to fit them to undertake the development of the mineral resources of the country, after a supplementary period devoted to practical work; and, secondly, to make use of the laboratories for tests, experiments, and investigations of practical utility to mining industries.

Mining Engineering.

The course of mining engineering is as follows:—

First Year.—Algebra, English, physics, projection-drawing, drill, rhetoric, physical laboratory work, geometry, descriptive geometry, and lettering.

Second Year.—Geometry, calculus, chemistry, general botany, modern language, drill, trigonometry and land-surveying, zoology, and topographical surveying and field work.

Third Year.—Analytical mechanics, mine-surveying, chemical laboratory work, modern language, resistance of materials, mineralogy, geology, dynamics, electrical engineering, and assaying.

Fourth Year.—Mining engineering, engineering geology, mining law, wind-wheels and hydraulics, practical work, metallurgy, mining accounts, mine administration, mine examination and report, thesis and practice.

Metallurgical Engineering.

The course in metallurgy is identical with the mining course in the first and second years; in the later years the course is as below:—

Third Year.—Architectural drawing and designing, mechanics, modern language, resistance of materials, mill work, mineralogy, geology, dynamics, analysis of ores, geology, assaying, and quantitative chemical laboratory.

Fourth Year.—Metallurgy, analysis of fuels, fluxes, etc., wind-wheels and hydraulic engines, mill accounts, practical mill-work, memoirs, administration, thesis and practice.

UNIVERSITY OF CALIFORNIA, SAN FRANCISCO, UNITED STATES.

The schools of the University of California are situated at various places in the State, and furnish instruction in literature and in science, and in the professions of law, medicine, dentistry, and pharmacy. In the colleges of letters, agriculture, mining, mechanics, civil engineering and chemistry, in the literary course, and in the course in letters and political science, these privileges are offered without charge for tuition, to all persons qualified for admission.

In the professional colleges in San Francisco, except that of law, moderate tuition fees are charged.

Eight regular courses of study are at present established, leading directly, under conditions hereinafter stated, to corresponding degrees, namely:—

Faculty of the college of letters, comprising:—(a) Classical course, leading to the degree of A.B.; (b) literary course, leading to the degree of B.L.; and (c) course in letters and political science, leading to the degree of Ph.B.

Faculties of the five colleges of science, comprising:—(a) Agriculture; (b) mechanics; (c) mining; (d) civil engineering; and (e) chemistry, each of which leads regularly to the degree of B.Sc.

COLLEGE OF MINING.

The college of mining is designed for students who wish to become mining or metallurgical engineers, or to engage in one of the many pursuits connected with mining industry, such as the surveying and mapping of mines, the assaying and extraction of ores, the designing and use of mining machinery, or the working of mines.

The undergraduate course may be completed by the average student in four years.

During the first two years considerable time is devoted to linguistic studies, embracing English prose style, to the preparation of summaries and précis writing, and to the acquisition of a reading knowledge of either French or German. Owing to the large and valuable scientific and technical literatures of these languages, it is important to the advanced student to be able to read them both. Only one is required of undergraduates, but both may be mastered during the course by a little extra effort. Those who have already a reading knowledge of either of these languages are advised to select the other in college. A knowledge of Spanish, while not required, will be of considerable advantage to mining students, as they will find many professional opportunities in Spanish-American countries. It may be easily acquired during the course. Preliminary to the strictly technical studies of the course, the student receives a sufficient training in those branches of modern physical science which lie at the basis of all the industries connected with mining: on the one hand, mathematics and its applications; and on the other, chemistry, mineralogy, petrography, and geology.

The mathematical studies are pursued with special reference to subsequent practical applications in surveying, physics, and analytical mechanics, which in their turn serve as a means for discussing such subjects as strength of materials and hydraulics. A similar sequence is observed with other studies; thus descriptive geometry is connected with work in the drawing-room, surveying with extensive field-practice and the mapping of surveys actually made by the student, physics with physical problems and work in the physical laboratory, strength of materials and hydraulics with original designs in the drawing-room, followed by working tests in the mechanical laboratory. These important studies extend through the whole four years' course; and inasmuch as they are peculiarly interdependent, it is necessary that they should be completed in the prescribed order, otherwise the student will find himself seriously embarrassed in his work.

The studies in chemistry and allied branches begin with general experimental chemistry, inorganic and organic, followed by analytical chemistry as an application, viz.: qualitative, quantitative and blowpipe analysis, subjects indispensable to subsequent work in metallurgy and assaying.

Having acquired a working power in chemistry, the student begins the study of mineralogy; this is followed by petrography, and by courses in general and field geology. These studies are developed with special reference to their applications in mining.

The technical branches of mining, metallurgy and assaying, peculiar to this college, are begun in the junior year, when the student has had sufficient training in the general and preparatory branches to study them with profit.

In the course in metallurgy, after the general consideration of the subjects which concern the treatment of all the metals, the rest of the undergraduate work is devoted to a detailed study of all the important methods in use for the reduction of the ores of lead, silver, gold, copper, and mercury.

The course concludes with a written thesis on some subject connected with mining or metallurgy, and leads to the degree of bachelor of science.

Candidates for the professional degrees in this college must satisfy the following conditions:—

Degree of Mining Engineer.—The candidate must be a graduate of the college of mining of this University, or give satisfactory evidence of having successfully pursued a course of study equivalent to its regular undergraduate course. He must also pass a satisfactory examination in the following subjects:—Mining, ore-dressing, petrography, economic geology, thermodynamics (elements), drawing

and construction of mining machinery, blowpipe assaying, and political economy. He must have had at least one year of actual practice in the field in the course chosen, and must show, by an original memoir upon some subject bearing upon this profession, power to apply his knowledge to practice. This degree will not be given earlier than three years after graduation.

Degree of Metallurgical Engineer.—The candidate must pass an examination in the following subjects:—Metallurgy, ore-dressing, assaying and analysis, blowpipe assaying, thermodynamics (elements), drawing and construction of furnaces and metallurgical machinery, and political economy. In all other respects the conditions are the same as those required for the degree of mining engineer.

COLORADO STATE SCHOOL OF MINES, GOLDEN, COLORADO, UNITED STATES.

The organization of the School of Mines of Colorado resembles that of the best technical schools of the United States. It is a school of applied science, in which, however, more than usual weight is given to those branches having a more or less direct bearing upon mining and metallurgy. All tuition is free.

There are four full courses of study, viz.:—Civil engineering, mining engineering, metallurgy, and electrical engineering. Each covers a period of four years. The studies, however, are identical during the first two years of all courses, beginning to diverge at the opening of the third year. The course in mathematics is taken in full by all, except the students in the metallurgical course.

The degrees given are:—(a) Civil engineer (C.E.); (b) engineer of mines (E.M.); (c) metallurgical engineer (M.E.); (d) electrical engineer (E.E.); and (e) bachelor of science (B.Sc.) The B.Sc. degree is given to any student of four years' residence, who, after having completed the course of the first two years, devotes himself for two more years to the study of analytical and theoretical chemistry. Such students are allowed to attend lectures in the higher classes on other topics than the specialty they have chosen, and must, during their last year, conduct some special research in analytical or technical chemistry.

Students will not be admitted to the fourth year as applicants for the degree of C.E. unless they have shown very marked ability in mathematics. They must also have been connected with some survey or other active field-operation on engineering lines during one of the vacations of their course.

Each student is required, during the summer vacation preceding his senior year, to execute a memoir on some assigned subject. At the end of the third year the student is also assigned a subject for a graduating thesis, such data being given as would be met with in practical experience.

The course of studies is as follows:—

First Year (for all courses).—Algebra, geometry, geology, freehand drawing, mechanical drawing, chemistry, and qualitative analysis.

Second Year (for all courses).—Plane and spherical trigonometry, descriptive geometry, qualitative and quantitative analysis, crystallography, physics, mechanical drawing, surveying, determinative mineralogy, algebra, shadows and perspective, stoichiometry, physical laboratory, and blowpipe work.

Mining Engineering.

The special courses in mining engineering for third and fourth years are as follow:—

Third Year.—Analytical geometry, differential and integral calculus, civil engineering, primary and secondary batteries, mining, quantitative analysis, mechanical drawing, metallurgy, mechanics, theory of strains, mining engineering, ore-dressing, electrical units, and vacation memoir.

Fourth Year.—Integral calculus, kinematics, mechanical drawing, mechanics, dynamics, theory of strains, economic geology, metallurgy, dynamo-electric machinery, distribution of electricity for lighting, thermodynamics, plans, constructions and estimates, mechanical engineering, electricity in mining, thesis work (including plans, estimates, and drawings), and long-distance transmission of power. In addition to the above schedule, one review study is taken in each term.

Metallurgical Engineering.

The special courses in metallurgy during the third and fourth years are as follows :—

Third Year.—Mining, quantitative analysis, metallurgical chemistry, civil engineering, metallurgy, mechanical drawing, mechanics, civil engineering, ore-buying and smelting-charges, ore-dressing, and a vacation memoir.

Fourth Year.—Kinematics, metallurgy, economic geology, plans, constructions, and estimates, theory of strains, applied chemistry, slag calculations, mechanical drawing, economics of metallurgy, dynamics, thermodynamics, mechanical engineering, and thesis work (including plans, estimates, and drawings). A review study is also taken in each term.

THE UNIVERSITY OF ILLINOIS, URBANA, CHAMPAIGN COUNTY, ILLINOIS, UNITED STATES.

The organization of the university comprises colleges of:—(a) Agriculture ; (b) engineering, with courses in mechanical engineering, electrical engineering, civil engineering, municipal and sanitary engineering, mining engineering, architecture, and architectural engineering ; (c) science ; (d) literature ; (e) additional schools of military science and of art and design ; together with (f) a graduate school.

COLLEGE OF ENGINEERING.

The courses of instruction comprise :—Mathematics—advanced algebra, trigonometry, conic sections, analytical geometry, differential calculus ; theoretical and applied mechanics—analytical mechanics, resistance of materials, hydraulics ; general engineering drawing—elements of draughting, descriptive geometry, lettering ; physics—elementary mechanics and sound, heat and light, electricity and magnetism ; mining engineering—mine attack, mine-surveying, ore-dressing, mine engineering ; civil engineering—land-surveying, topographical drawing and surveying, transit surveying and levelling, railroad-engineering, masonry-construction, geodesy, practical astronomy, bridges.

Labour is furnished as far as possible to all who desire it. It is classified into educational and remunerative labour. Educational labour is designed as a practical instruction, and constitutes a part of the course in several schools. Students are credited with their proficiency in it as in other studies. Nothing is paid for it. Remunerative labour is prosecuted for its products, and students are paid what their work is worth. The usual rate paid for ordinary farm, garden, and shop labour is 6d. per hour. Students of sufficient experience may be allowed to work by the piece or job, and thus by diligence or skill secure more pay.

Some students who have the requisite skill, industry, and economy, pay their entire expenses by their labour; but, in general, young men cannot count upon doing this at first, without a capital to begin with, either of skill, or money to serve them till a degree of skill is acquired.

The tuition is free in all the university classes. The cost of residence varies from £30 to £60.

Mining Engineering.

The course comprises the greater part of the pure and applied mathematics of the courses in mechanical and civil engineering. Much time is devoted to chemistry and geology, with the addition of metallurgy and other technical studies peculiar to mining engineering. Students who are graduated from this course are not supposed to be familiar with all the details of mine management from actual experience, but they will have obtained such a knowledge of the principles underlying all successful practice, and such a familiarity with the science of mining in all its branches, that the art may be acquired with the minimum of practice.

Plans, estimates, drawings, reports, and calculations, based upon data obtained in the student's own experience, are constantly required, and no pains are spared to familiarize each member of the class with the duties and responsibilities of every grade, from miner to manager.

The course of the studies is:—

First Year.—Algebra, elements of draughting, chemistry, French, German, or English, trigonometry, descriptive geometry and lettering, analytical geometry, freehand drawing, and military.

Second Year.—Differential and integral calculus, land-surveying, physics, analytical geometry, topographical drawing and surveying, transit-surveying and levelling, French, German, freehand drawing (optional), and military.

Third Year.—Analytical mechanics, mine attack, mineralogy, resistance of materials, assaying, geology, hydraulics, roofs, chemistry, mine surveying, themes and elocution.

Fourth Year.—Mine engineering, ore-dressing, heat engines, geology, hydraulic engines and wind wheels, chemistry, political economy, roofs, and metallurgy.

Degrees.

The usual bachelor's and master's degrees are conferred upon those who satisfactorily complete the courses of study described in the different colleges. A candidate for a bachelor's degree must pass in the subjects of his chosen course, and must conform to the directions given in connexion with that course in regard to optional subjects.

In all cases an accepted thesis is required for graduation, based upon original research, and must contain at least 2,000 words, or an equivalent in tables, drawings, and illustrations.

The degree of bachelor of science will be given to those who complete a course of study in the college of engineering, of agriculture, or of science. The name of the course will be inserted after the degree.

The master's degrees, M.A., M.L., and M.S., and the equivalent degrees of civil engineer and mechanical engineer, etc., will be given, after 1894, to graduates of this or other similar institutions who have pursued at this university a year of prescribed graduate studies and have passed examinations thereon, or who have pursued as non-residents three years of such study and have passed the required examinations. Studies for a master's degree must be in the general line

of the bachelor's degree already received, and of the degree sought. In all cases an accepted thesis is required and this should be presented at least one month before the close of the collegiate year. It must be based upon original research and must show scholarly acquirements of a high order.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, BOSTON,
UNITED STATES.

The Massachusetts Institute of Technology includes a Society of Arts, a Museum of Arts, and a School of Industrial Science.

The School of Industrial Science is devoted to the teaching of science as applied to the various engineering professions—namely, civil, mechanical, mining, electrical, chemical, and sanitary engineering, as well as to architecture, chemistry, metallurgy, physics, and geology. Courses of a less technical nature, designed as a preparation for business callings, and a course in biology preparatory to the professional study of medicine, are also given.

The subjects of study have been arranged in twelve distinct formulated courses, each of four years' duration. For the satisfactory completion of any one of these, the degree of bachelor of science is conferred. Of twelve courses, seven give their students scientific and practical training for the various engineering professions; those in chemistry, physics, biology, and geology, having a larger proportion of pure science, afford preparation either for professional practice, for teaching, or for scientific investigation.

In the first year all the courses are the same, and contain subjects which are considered essential for the more strictly professional studies of the later years. At the end of the year the regular student selects the course which he will pursue during the remaining three years, and his work becomes more specialized thereafter as it progresses.

Within most of these regular courses the student is given a considerable latitude in the selection of the branch of his intended profession to which he will specially devote his energies in the later years of his study. This is accomplished by means of options. Thus in civil engineering he may elect sanitary and hydraulic engineering, geodesy, or an advanced course in railroad engineering and management.

Regular Courses.

First Year.—The studies are common to all regular courses as follow:—Solid geometry, algebra, chemistry, chemical laboratory work, rhetoric and English composition, French or German, mechanical drawing, freehand drawing, plane and spherical trigonometry, political history since 1815, and military drill.

Mining Engineering and Metallurgy.

Second Year.—Analytical geometry, physics, German, American history, descriptive geometry, differential calculus, English literature and composition, mineralogy and blowpipe analysis (silver assay), and optional subjects:—(a) Principles of mechanism, use of surveying instruments; (b) surveying, topographical drawing; (c) mechanism: cotton machinery, machine tools, drawing, physical geography; (d) surveying and drawing, physical geography. This may be accompanied by a summer course in practical mining or metallurgy and field-work in mineralogy.

Third Year.—Integral calculus, general statics, physics, strength of materials, kinematics and dynamics, physical laboratory work, German, assaying, mining engineering, geology, and optional subjects:—(a) Steam engineering valve-gears, thermodynamics, drawing; (b) railroad and highway-engineering; (c) steam

engineering, boilers, engineering laboratory work; (d) railroad and highway engineering. This may be followed by a summer course in practical metallurgy or mining.

Fourth Year.—Metallurgy, metallurgy of iron, mining engineering, dynamos, mining laboratory work, memoirs, and optional subjects:—(a) Strength of materials, friction, steam engineering and hydraulics, engineering laboratory work; (b) strength of materials, theory of elasticity, theory of structures, hydraulics, hydraulic measurements; (c) strength and stability of structures, theory of elasticity, technical machinery, engineering laboratory work; (d) theory of structures, electric railroads, hydraulic engineering.

Another course of instruction is:—

Second Year.—Analytical geometry, physics, German, American history, theoretical chemistry, differential calculus, English literature and composition, mineralogy and blowpipe analysis, and optional subjects:—(a) Descriptive geometry, principles of mechanism, blowpipe (silver assay); (b) surveying, topographical drawing, blowpipe assay; (c) mechanism: cotton machinery, machine-tools, drawing; (d) surveying and drawing, physical geography. This may be accompanied by a summer course in practical mining or metallurgy and field-work in mineralogy.

Third Year.—Integral calculus, general statics, physics: heat, strength of materials, kinematics and dynamics, physical laboratory work, German, assaying, analytical chemistry, and optional subjects:—(a) Steam engineering, thermodynamics, valve-gears, drawing; (b) mining engineering, geology; (c) steam engineering, boilers, engineering laboratory work; (d) mining engineering, geology, electricity. This may be followed by a summer course in practical mining or metallurgy.

Fourth Year.—Strength of materials, friction, mining engineering, analytical chemistry, metallurgy, memoirs, metallurgical and chemical laboratories work, and optional subjects:—(a) Hydraulics, dynamos, English criticism; (b) electricity, political economy and industrial history, commercial law; (c) engineering laboratory work, technical machinery, English criticism; (d) mining engineering, political economy and industrial history, commercial law.

Summer Schools of Mining and Metallurgy are organized for the study of mines, mills, smelting-works, and geological fields. Since the year 1870 these schools have made studies in Colorado, Michigan, Virginia, Vermont, Pennsylvania, Lake Champlain, New Brunswick, and Nova Scotia.

Graduation.

The degree of bachelor of science, in the course pursued, is given for the satisfactory completion of any regular course of study. To be entitled to a degree, the student must have passed satisfactory examinations in all the prescribed studies and exercises, and, if required, a final or degree examination, embracing all the subjects which particularly relate to his course. He must, moreover, prepare a dissertation on some subject included in his course of study; or an account of some research made by himself; or an original report upon some machine, work of engineering, industrial works, mine, or mineral survey; or an original architectural design, accompanied by an explanatory memoir.

The tuition fee for regular students is £40 per year.

Students may conveniently live in any of the neighbouring cities or towns on the lines of the various railroads, if they prefer to do so. The cost of board and rooms in Boston and the neighbouring cities and towns need not exceed from £1 10s. to £2 per week.

UNIVERSITY OF MICHIGAN, ANN ARBOR, MICHIGAN, UNITED STATES.

The University of Michigan is a part of the public educational system of the State, and aims at completing the work that is begun in the public schools by furnishing ample facilities for a liberal education in literature, science, and the arts, and for a thorough professional study of medicine, pharmacy, law, and dentistry. The doors of the institution are open to all students, wherever their homes.

The matriculation fee for citizens of Michigan is £2, and, for those who come from any other state or country, £5, is paid but once, and entitles the student to the privileges of permanent membership of the university. In addition to the matriculation fee, every student has to pay an annual fee for incidental expenses. Resident graduates are required to pay the same annual fee as undergraduates.

Students obtain board and lodging with private families for about £1 a week. The annual expenses of students, including clothing and incidentals are, on the average, about £80. The university does not undertake to furnish manual labour to students; yet a few find opportunities in the city for remunerative labour.

The university offers to persons who wish to become professional engineers thorough courses of study extending over about four years.

In civil engineering all the technical branches are under the direct care of those who have had professional experience as well as a full scientific training, and in all particulars the course embodies as close an imitation of the requirements of active labour as the instructors who have the several branches in charge can devise.

In mechanical engineering the course of study includes a wide range of special studies. Prominence is given to the study of steam engineering, and in this branch a large amount of practical work is done. The instruction is arranged to accommodate those who wish to devote their time principally to mechanical engineering proper, to steam engineering, or to marine engineering and naval architecture.

In mining engineering and metallurgy the course of instruction, which is intended to cover about four years of study, includes a part of that provided for students in civil and in mechanical engineering, though more especial attention is paid in the latter part of the course to mineralogy, geology, and chemistry. The instruction in the technical branches is arranged so as to meet the wants, both of those whose purpose it is to confine their professional work more closely to metallurgy, and of those who intend to engage in the practice of mining and metallurgy combined.

In electrical engineering the first three years of the course are nearly the same as in mechanical engineering. Besides the preliminary work in mathematics, language, drawing, and physics, instruction is given to pattern making, metal work, forging, and foundry work; and enough of the study of steam engines and other prime movers is included to meet the needs of the professional electrical engineer.

The courses of instruction comprise mathematics (algebra, trigonometry, analytical geometry, and the elements of differential and integral calculus), French and German, English grammar and composition, physics, chemistry, drawing, practice in geometrical and in mechanical drawing, and in the study of descriptive geometry.

The more technical subjects are taken up in the latter part of the course. Some of these subjects are of equal value to all classes of engineering students, such as analytical and applied mechanics, the strength and resistance of materials, and the metallurgy of the useful metals, especially iron and steel; others are adapted more particularly to the wants of the special students in the several courses.

Upon the completion of a prescribed course of study, amounting to twenty-five full courses, and the presentation of a satisfactory thesis, the student receives the degree of bachelor of science. The diploma given indicates the line of study pursued.

Bachelors of arts, of philosophy, of science, and of letters, of this university, and graduates of any other reputable college, are recommended for the same degree with the regular students, after attendance on, and a satisfactory examination in, the technical subjects alone of the several courses. These studies can be completed in two years.

Mining Engineering.

To obtain the recommendation of the faculty for the degree of bachelor of science for a course in mining engineering, the student must satisfy one of the two following sets of requirements:—Mining (French and German, English, mathematics, physics, chemistry, analytical chemistry, mineralogy, geology, drawing, surveying, civil engineering, mechanical engineering, mining engineering, metallurgy); or Metallurgy (French and German, English, mathematics, physics, general chemistry, analytical chemistry, mineralogy, geology, drawing, mechanical engineering, mining engineering, and metallurgy).

The Degree of Civil Engineer, Mechanical Engineer, Mining Engineer, and Electrical Engineer.

The degree of civil engineer may be conferred upon bachelors of science of this university who have taken the degree for a course in civil engineering if they furnish satisfactory evidence that they have pursued further technical studies for at least one year, and, in addition, have been engaged in professional work, in positions of responsibility, for another year. The first of the above requirements may be satisfied by pursuing at the university, under the direction of the faculty, a prescribed course of study for an amount of time, not necessarily consecutive, equivalent to a college year. If the candidate does not reside at the university, his course of study must be approved in advance by the professor of civil engineering, and he must prepare a satisfactory thesis on some engineering topic, to be presented, together with a detailed account of his professional work, one month, at least, before the date of the annual commencement at which he expects to receive the degree. The conditions on which the degrees of mechanical engineer, mining engineer, and electrical engineer, as second degrees, are conferred upon bachelors of science of this university who have taken the degree for a course in mechanical engineering, in mining engineering, or in electrical engineering, are analogous in character to those enumerated for the degree of civil engineer.

Doctors' Degrees.

Doctors' degrees are conferred only on persons who have previously received a bachelor's degree, either here or at some other reputable university or college, and also during residence here have made special proficiency in some one branch of study, and good attainments in two other branches, and have presented a thesis that shall evince the power of research and of independent investigation. It is not intended that the doctors' degrees shall be won merely by faithful and industrious work for a prescribed time in some assigned course of study, and no definite term of required residence can be specified; but it is the practice of the university to require at least one full year of residence of candidates that have already earned a master's degree, and at least two full years of candidates that have previously taken only a bachelor's degree.

The degree of doctor of philosophy is open to persons that have received the degree of bachelor of arts, or of bachelor of philosophy; the degree of doctor of science to persons that have received the degree of bachelor of science; and the degree of doctor of letters to persons who have received the degree of bachelor of letters.

THE MICHIGAN MINING SCHOOL, HOUGHTON, MICHIGAN, UNITED STATES.

Mining only is taught at this school. It is situate in Houghton county, in the Portage lake copper-mine district, and within easy reach of the Keweenaw and Ontonagan copper districts, and the iron-mining regions of Marquette, Menominee, and Gogebic.

The course of instruction for the regular students extends over a period of three years, effecting a saving of time in years by continuing the work through most of the year, and by making the course strictly professional and technical:—

First Year.—Mathematics, drawing, physics, chemistry, surveying, mineralogy and lithology, physical, chemical and mineralogical laboratories.

Second Year.—Differential and integral calculus, drawing, properties of materials, chemistry, qualitative and quantitative analysis, metallurgy, petrography, mechanics, applied mechanics, mechanism, electricity, mining, mine-surveying, stratigraphical geology and palæontology, machine shop, and chemical laboratory.

Third Year.—Graphical statics, quantitative analysis, metallurgy, ore-dressing, mechanics of materials, mechanical engineering, electrical engineering, physical geology, metallurgical analysis, assaying, practical geology, mining engineering and mine accounts, hydraulic and structural engineering, economic geology, and chemical laboratory. The student may also take engineering design and electric motors and their applications, or chemical analytical methods. Every student who is pursuing the regular course is required to select either engineering design and electrical engineering, or technical chemistry.

In order to be able to give more time to the technical parts of the education of a mining engineer, it is proposed to lengthen the course of study to four years.

Every student completing the three years' course is required to present to the faculty a satisfactory thesis, embodying the results of an investigation upon some subject related to the studies of that course, before he can be recommended to receive his degree. Students intending to graduate in any year are required to select their subjects and present them to the faculty for approval by the 1st of March of that year.

Under the act of organization the board of control have made the school entirely free, no charge being made for tuition or incidentals, whether the student be a resident of the State of Michigan or of the United States or not; all has been made free to the students from every land.

Arrangements are made whereby those who desire to do so can obtain board and rooms in private families, and in boarding-houses, in Houghton and Hancock, at prices varying from £3 to £5 per calendar month. The necessary expenses of the student may be estimated at about £50 to £90 per annum.

Degrees.

Students who complete the present course of three years, and present a satisfactory thesis, will receive the degree of mining engineer or engineer of mines

(E.M.). The thesis must conform to the requirements detailed above, and must be completed and approved by the faculty before that body will recommend that the degree of mining engineer or engineer of mines, be conferred upon the student.

Those who wish to become candidates for a higher degree will enter under the following terms:—Students who are graduates of this institution, or of others of similar grade, whose course shall be approved by the faculty, will be admitted as candidates for the degree of doctor of philosophy. In order to attain this degree they must pursue for at least two years an advanced course of study in subjects germane to the undergraduate course in this institution, which course of study is to be approved by the faculty. One of the years of study may, in special cases, be spent elsewhere, and the work accepted, on sufficient proof of its thoroughness and high character, as the equivalent of one year's work spent here. But under no condition will the degree be given unless one year at least is spent as a resident worker at this institution.

Students who are both graduates of this or of an equivalent professional school, and also of some college or university whose course of study is accepted by the faculty, may be admitted to the degree of doctor of philosophy, after taking for at least one year an approved course of study at this institution. The degree of doctor of philosophy will only be given in case the student shall have shown marked ability, power for original investigation, has passed a satisfactory oral public examination, and presented a thesis embodying the result of original investigation, which has been approved by the faculty.

Students who are graduates of this or of other institutions having a satisfactory equivalent course, and who shall have pursued here, according to the above regulations, a successful course of study for the degree of doctor of philosophy, may at the same time receive the degree of mining engineer, if that degree has not been conferred at their previous graduation.

THE UNIVERSITY OF MINNESOTA, MINNEAPOLIS, UNITED STATES.

The University of Minnesota is a State institution, being a part of the State educational system. It is situated in the city of Minneapolis, about a mile below and in full view of the Falls of St. Anthony.

The university is composed of the following colleges:—(a) Science, literature and arts; (b) engineering, metallurgy and mechanical arts; (c) agriculture, etc.

The university has no dormitories, except for the school of agriculture, but students find no difficulty in obtaining board among the people of the city. Good board can be obtained in private families at prices ranging from £1 upwards per week.

The university cannot promise employment to those desiring to earn their own living. The public bounty stops at furnishing free instruction. Many of the students support themselves while in college, and a young man who really wants work, and will look for it, can generally find it.

The average necessary annual expenses of students boarding in families appear to be about £60, those of students boarding in clubs about £40.

THE COLLEGE OF ENGINEERING, METALLURGY, AND THE MECHANICAL ARTS.

In this college there are seven regular courses of study, viz., civil engineering, mechanical engineering, electrical engineering, architecture, mining, chemistry, and metallurgy leading to the corresponding bachelor's degrees.

Mining Engineers.

The courses of study in mining are as follows :—

First Year.—Algebra, German or French, chemistry, chemical laboratory work, drawing, trigonometry, qualitative analysis, carpentry, surveying, and military drill.

Second Year.—Analytical geometry, French or German, topography, draughting, physics, mineralogy, differential and integral calculus, descriptive geometry, quantitative chemical analysis, and quantitative blowpipe assaying.

Third Year.—Mechanics, geology, quantitative chemistry, assaying, mining, metallurgy, mechanical laboratory work, machine design, lithology, ore-testing and dressing, drilling and blasting, applied geology, and technical essay.

Fourth Year.—Methods and machinery for extracting minerals and ores, metallurgy, geology, electrical engineering, law (optional), prospecting, exploration of mines, etc., hydraulics, steam engines and motors, designs and specifications, mine engineering, and thesis (optional).

Metallurgical Engineering.

The courses of study in metallurgy are :—

First Year.—Algebra, German or French, chemistry, chemical laboratory work, drawing, trigonometry, qualitative analysis, carpentry, surveying, and military drill.

Second Year.—Analytical geometry, French or German, topography, draughting, physics, mineralogy, differential and integral calculus, descriptive geometry, quantitative chemical analysis, and quantitative blowpipe analysis.

Third Year.—Mechanics, geology, quantitative chemistry, assaying, mining, metallurgy, mechanical laboratory work, machine design, lithology, ore-testing and dressing, applied geology, and technical essay.

Fourth Year.—Mining, metallurgy, geology, electrical engineering, law (optional), hydraulics, steam engines and motors, designs and specifications, and thesis (optional).

UNIVERSITY OF MISSOURI, ROLLA, MISSOURI, UNITED STATES.

The School of Mines and Metallurgy is an institute of technology, and constitutes one of the colleges which, taken together, form the University of the State of Missouri.

The course of instruction at this school deals in detail with the principles and the practice of engineering, with special reference to mining engineering, civil engineering, mechanical engineering, chemistry and metallurgy, mathematics, physics and electricity.

At the close of the year each member of the senior class presents a paper in which he records some independent investigation, in a subject congenial to his tastes, and included in the scope of his course.

Provision is now made for the following technical courses:—(a) Mining engineering; (b) civil engineering; (c) mechanical engineering; (d) chemistry and metallurgy; and (e) mathematics and physics. For the satisfactory completion of any one of these courses the degree of bachelor of science will be given.

The requisites for admission to any of these courses are passing grades in the subjects taught in the preparatory course. The first year is the same for the engineering courses; the selection being made at the beginning of the second year.

In addition to the regular courses outlined above, provision is made for special courses in assaying, surveying, and electricity. For the satisfactory completion of these subjects a certificate of proficiency will be given. The requisite for admission to one of these courses is a knowledge of the preparatory studies of that subject.

Preparatory Course.

The course of study is :—

First Year.—Higher arithmetic, English grammar, composition and rhetoric, algebra, United States history, physiology and hygiene.

Second Year.—English, algebra, physics, solid and plane geometry, and chemistry.

A matriculation fee of £2 is payable on entrance, and a library fee of 10s. a term, payable on the first day of each term, is required of every student. The cost of books and stationery may be assumed to average £2 during the session. Board, including fuel, lights, washing, etc., can be obtained for £2 to £3 a month. The necessary expenses for the school year are from £25 to £40.

Engineering Courses.

The higher courses of study are as follows :—

First Year.—General chemistry, elementary mechanics, descriptive geometry, stereotomy, trigonometry, analytical geometry, chemical laboratory work, field-work, and drawing.

Mining Engineering.

Second Year.—Analytical geometry and calculus, assaying, physics, chemical technology, mineralogy, geology, civil engineering, mining engineering, chemical laboratory work, and physical laboratory work.

Third Year.—Analytical mechanics, metallurgy, electric transmission of energy, dynamo-electric machinery, mining engineering, physical laboratory work, chemical laboratory work, and thesis.

Degrees.

A diploma of graduation is conferred on one who has passed all examinations in any of the following departments :—Mathematics, physics, analytical chemistry, engineering, and the academic course.

The degree of bachelor of science in mathematics and physics is conferred upon one who has passed examination on all of the subjects of instruction in the course of mathematics and physics.

The degree of bachelor of science in civil engineering is conferred on one who has passed examination on all of the subjects of instruction in the civil engineering course.

The degree of bachelor of science in mining engineering is conferred on one who has passed examination on all of the subjects of instruction in the mining engineering course.

The degree of bachelor of science in mechanical engineering is conferred on one who has passed examination on all of the subjects of the mechanical engineering course.

The degree of civil engineer, mining engineer, or mechanical engineer is conferred on one who, having graduated in civil, mining, or mechanical engineering, and having received the bachelor's degree therein, has identified himself with the profession during a period of not less than three years, and during that time has demonstrated by work his fitness for his chosen profession.

WASHINGTON UNIVERSITY, ST. LOUIS, MISSOURI, UNITED STATES.

Washington University, founded in the city of St. Louis under an Act of Incorporation by the State of Missouri, approved February 22nd, 1853, is intended to embrace the whole range of university studies, except theology, and to afford opportunity of complete preparation for every sphere of practical and scientific life.

THE POLYTECHNIC SCHOOL.

The courses of study in the Polytechnic School are seven in number, viz. :—(a) Civil engineering ; (b) mechanical engineering ; (c) electrical engineering ; (d) chemistry ; (e) mining and metallurgy ; (f) science and literature ; and (g) special studies and investigations in pure and applied science.

The tuition fee in the undergraduate department is £30 a year. The yearly expenses may range, according to tastes and habits of economy, from £75 to £100.

The studies are the same for all the courses during the first and second years, but during the later years they diverge widely.

First Year.—Higher algebra, pneumatics, heat, laboratory work, French or German, mechanical drawing, English composition, orthographic projections, use of joiner's tools, ethics, plane trigonometry, optics, freehand drawing, descriptive geometry, chemistry, history of England, elocution and composition, and practical wood turning and pattern making.

Second Year.—Analytical geometry, electricity, magnetism, and laboratory work ; use of surveying instruments ; land, topographical, and mining surveying ; field practice, descriptive geometry, sketching, brush shading, topographical and isometric drawing, practical forging iron and steel, differential calculus, hydrographic and railway surveying, curves and turnouts, earth-work, graphical statics in mechanics, qualitative chemical analysis, acoustics and laboratory work, French or German and English.

Every student is required, during the vacations following the first and second years, to prepare reports upon suitable engineering methods or constructions from personal examinations and studies.

Mining and Metallurgy.

Third Year.—Integral calculus and applications, zoology, analytical statics, dynamics, qualitative chemical analysis (lectures and laboratory practice), qualitative blowpipe analysis, crystallography, mineralogy, botany, assaying, metallurgy, drawing (sections, crystals, plans and sections of mines and mining machinery, furnaces, apparatus and machinery of smelting-works, etc.), practical hand and machine-tool work on metals, sampling, hand-panning, fuel tests, mechanics, steam engineering, engineering structures, geology, and mining.

Fourth Year.—Mining, metallurgy, economic geology, quantitative analysis of ores, blowpipe analysis, mechanics, designs, estimates and specifications of mining and metallurgical structures, working tests in gold and silver-milling and concentration, electricity, strength of materials, political economy, electricity and magnetism, assaying, engineering, and lithology.

Fifth Year.—Metallurgy, electricity, economic geology, field geology, quantitative analysis, micro-lithology, mining, ore-dressing, mill-work, thermodynamics, mining law, forms and accounts, commercial practice, qualitative analysis, palæontology, and thesis on the establishment and working of mines and smelting-works under given conditions (with drawings, estimates, and written memoirs).

During the summer vacation a school for practical work is held for about two months in some mining district. All the students of the mining department and those about to enter the course of mining and metallurgy after having completed

the two years of preparatory work are required to take part in the work of the summer school. In this way each student receives the benefit of three seasons of practical work in connexion with the course. While in the field the students are under the constant supervision of an assistant, and are required to make complete surface and underground surveys, take sketches and notes of all machinery and appliances used, and as far as possible take part in the practical operations connected with the mining and treatment of ores, etc. During the following term full reports are prepared and handed in, illustrated with accompanying drawings and collections of specimens.

Degrees.

The degrees corresponding to the two courses of study conferred upon the satisfactory completion of the four years' work are :—(1) The degree of bachelor of arts ; (2) the degree of bachelor of philosophy.

The degrees granted upon the completion of the several courses of study fall into two classes : professional and non-professional. The only degree conferred upon students in the professional courses (engineering and chemistry) is the professional degree at the completion of the fifth year's work. No professional or master's degree is given at the close of the fourth year.

The degrees corresponding to the courses of study given on the completion of the work as prescribed are :—(a) Civil engineer ; (b) dynamic engineer ; (c) chemist ; (d) engineer of mines ; (e) bachelor of science ; and (f) master of science.

The degree of master of arts is open to all who have received from this university the degree of bachelor of arts.

The degree of master of philosophy is open to all who have received from this university the degree of bachelor of philosophy.

The degree of master of science is open to all who have received from this university the degree of civil engineer, of dynamic engineer, of chemist, or of engineer of mines, as well as to those who shall have pursued the special five years' course prescribed for this degree.

The degree of doctor of philosophy is open to all who have received the degree of master from this university.

In no case will the degree of master, as a second degree, be conferred in less than two years after the date of the lower degree, nor that of doctor in less than one year after the date of the master's degree ; nor will such degrees be recommended except upon satisfactory evidence, to be determined by examination, of a proper amount of study and attainment in advance of undergraduate work.

COLLEGE OF MONTANA, DEER LODGE, MONTANA, UNITED STATES.

The college presents four distinct courses of study, the classical, the scientific, the school of mines, and the English and normal department.

The instruction in the academy is given by the members of the faculties of the college and school of mines. The course of instruction has been prepared with a view to a thorough preparation for the several advanced courses, and at the same time is complete in itself, and well adapted to those who seek only a foundation for the ordinary business of life.

THE SCHOOL OF MINES.

The scheme of work for the course in mining engineering is appended ; the course in civil engineering is somewhat similar, but with such modifications as may seem necessary.

The degree of E.M. is given to graduates in the school of mines.

Mining Engineering.

The course of lectures is:—

First Year.—Trigonometry, analytics, general chemistry, German, or some selected language, qualitative analysis, botany, and English.

Second Year.—Analytics, calculus, chemical physics, chemical philosophy, physics, quantitative analysis, descriptive geometry, metallurgy, crystallography, and theoretical mineralogy.

Third Year.—Calculus, mechanics, metallurgy, geology, mechanical engineering, mining engineering, civil engineering, strains in structures, lithology, and mineralogy.

Fourth Year.—Assaying, railroad engineering, strains in structures, ore-dressing, hydraulic engineering, properties of materials, economic geology, applied chemistry, sanitary engineering, heating and ventilation, graphical statics, and lithology.

The practical work during the same period is:—

First Year.—Qualitative chemical analysis and mechanical drawing.

Second Year.—Quantitative chemical analysis, crystallography, and blowpipe analysis.

Third Year.—Mechanical drawing, surveying, blowpipe analysis, and determinative mineralogy.

Fourth Year.—Petrography, railroad surveying, assaying, graphical statics, and engineering designing.

During the vacation at the end of the third year the students in mining engineering are expected to visit a number of mines, and to make a thorough study of at least one or two of them.

During the fourth year each of the students is required to present to the professor of engineering a memoir giving a detailed description of the mines studied during the vacation, and illustrated with drawings carefully made to scale. These memoirs become the property of the engineering department, and are kept for reference purposes.

The advantages of this institution, its various courses of study, are offered to students of both sexes on the same terms. The ladies and gentlemen meet in the dining hall, in the chapel, in the class-rooms, and on such social occasions as the faculty may arrange or approve.

Employment is given to a limited number of students in the care of the buildings and in services in the dining-room, by which part or all of the necessary expenses are met. Rooms may be obtained in town for self-boardings at reasonable rates.

Board at the college includes furnished room, with heat and lights, three meals per day, laundry (not exceeding fifteen pieces per week), mail delivery three times a day, the use of bath-room, reading-room, and library, per month of four weeks, £6. The entire expenses for board and tuition for the college year are £70.

COLUMBIA COLLEGE, CITY OF NEW YORK, UNITED STATES.

Columbia College consists of the school of arts (the original college, founded in 1754); of sundry professional schools, to wit: the school of law, the school of mines, and its medical department by joint resolution, the college of physicians and surgeons, admission to all of which, as candidates for professional degrees, is open to all students whether or not they are college-bred men; and of the univer-

sity faculties of law, mines (mathematics and pure and applied science), political science, and philosophy, which conduct all courses leading to the university degrees of master of arts and doctor of philosophy.

The point of contact between the college and the university is the senior year in the school of arts, during which year students in the school of arts pursue their studies, with the consent of the faculty of arts, under one or more of the university faculties. The various schools are under the charge of their own faculties, and for the better conduct of the strictly university work, as well as of the whole institution, a university council has been established.

THE SCHOOL OF MINES.

In the School of Mines, the system of instruction includes:—1. Regular undergraduate courses in (a) mining engineering; (b) civil engineering; (c) electrical engineering; (d) metallurgy; (e) geology and palæontology; (f) analytical and applied chemistry; and (g) architecture. 2. Post-graduate courses in (a) electrical engineering; (b) sanitary engineering; and (c) special.

Under the university faculty of mines there is instruction in elective courses for the degree of (a) master of arts; (b) doctor of philosophy; and (c) special courses.

The annual tuition fee for undergraduate students is £40. It is the desire of the trustees to extend, as widely as possible, the educational advantages of the college to deserving young men. Free tuition is therefore offered to undergraduate students under certain conditions which need not be specified here.

Mining Engineering.

The course of study is as follows:—

First Year.—Trigonometry, heat, sound, surveying, botany, chemistry, qualitative analysis, blowpipe analysis, algebra, analytical geometry, descriptive geometry, magnetism, electricity, light, crystallography, drawing, and surveying.

Second Year.—Analytical geometry, calculus, graphics, excavation, biology, hygiene, applied chemistry, mineralogy, tunnelling, drawing, and surveying.

Third Year.—Analytical mechanics, electricity, engineering, properties of materials, graphical statics, mining, geology, assaying, metallurgy, physical laboratory practice, drawing, practical mining, and railroad surveying.

Fourth Year.—Mining, machinery and mill-work, mechanical engineering, heat and its applications, economic geology, metallurgy, ore-dressing, quantitative analysis, assaying, and project or thesis.

Metallurgical Engineering.

The course of study is as follows:—

First Year.—Trigonometry, algebra, heat, sound, magnetism, electricity, light, surveying, chemistry, qualitative and blowpipe analysis, analytical and descriptive geometry, crystallography, drawing, and surveying.

Second Year.—Analytical geometry, calculus, graphics, excavation, tunnelling, hygiene, applied chemistry, quantitative analysis, mineralogy, drawing, and surveying.

Third Year.—Analytical mechanics, electricity and laboratory practice, engineering, properties of materials, graphical statics, mining, geology, quantitative analysis, metallurgy, assaying, drawing, and practical mining.

Fourth Year.—Machinery and mill-work, heat and its applications, economic geology, metallurgy, ore-dressing, quantitative chemical analysis, mining, mechanical engineering, assaying, and project or thesis.

During the vacation at the end of the third year a class in practical mining, composed of students in the course of mining engineering, and in the course of metallurgy, who have completed their third year, is required to visit mines for practical mining work.

During the latter part of the vacations following the close of the first and second years, students in the courses of mining and civil engineering, metallurgy, and geology are required to join the summer class in surveying under the direction of the assistant professor of civil engineering.

During the vacation following the close of the third year students in the courses of mining engineering and metallurgy are required to visit mines and engage in actual work or study under the superintendence of the assistant professor of mining.

Every student who has passed satisfactory examinations is recommended for the degree of engineer of mines, civil engineer, metallurgical engineer, etc.

Degrees.

Any student who has taken his bachelor degree either in Columbia College or in some other college maintaining an equivalent curriculum (every such case of equivalence to be considered on its own merits) shall be entitled, with the approval of the president, to become a candidate for the degrees of master of arts and doctor of philosophy, or either of them.

Each student who declares himself a candidate for the degrees of master of arts and doctor of philosophy, or either of them, shall, immediately upon registration, designate one principal or major subject and two subordinate or minor subjects, which, when approved by the proper faculty, shall be the studies of his university course.

Candidates for the degrees of master of arts and doctor of philosophy, or either of them, must pursue their studies under the direction of the professors and other officers of instruction in charge of the subjects selected by the candidates.

Each candidate for the degree of master of arts, in addition to passing satisfactory examinations on prescribed portions of the subjects selected by him as major and minor, shall present an essay on some topic previously approved by the professor in charge of his major subject.

Each candidate for the degree of doctor of philosophy, in addition to passing satisfactory examinations on the subjects selected by him as major and minor, shall present a dissertation embodying the result of original investigation and research, on some topic previously approved by the faculty.

Every candidate for the degree of doctor of philosophy, in addition to passing such other examinations as may be required by the faculty, shall be subjected to an oral examination on his major subject, and shall defend his dissertation in the presence of the entire faculty, or of so many of its members as may desire to attend. The ability to read at sight two or all of the following languages:—Latin, French, and German—as each faculty may determine, will also be required.

For the degrees of master of arts and doctor of philosophy, or either of them, the course of study shall, so far as possible, embrace instruction in the following groups of subjects:—(a) Mathematics; (b) mechanics, physics, and chemistry; (c) biology, botany, paleontology, mineralogy, lithology, geology, astronomy, meteorology, physical geography, geodesy, and surveying; (d) Engineering (civil, mechanical, electrical or sanitary), mining, metallurgy, and architecture. No candidate for a degree may select more than two of his subjects from any one group.

Candidates for the degree of doctor of philosophy, whose preparatory training is purely scientific, will be required to select, for not less than one year, a minor course, under the direction of either the faculty of philosophy or the faculty of political science.

THE OHIO STATE UNIVERSITY, COLUMBUS, OHIO, UNITED STATES.

The university comprises the collegiate department, the law school, and a preparatory department.

The collegiate department embraces schools of arts and philosophy, science, agriculture, engineering, pharmacy, and veterinary medicine.

The instruction given in the collegiate department of the university embraces a wide range of subjects, in accordance with the following classification:—Agriculture, agricultural chemistry, astronomy, botany, civil engineering, drawing, electrical engineering, chemistry, geology, English and rhetoric, French, German, Romance languages, Spanish, Greek, Italian, Latin, history, horticulture, mathematics, mechanical engineering, metallurgy, mine engineering, military science and tactics, pharmacy, philosophy, physics, physiology, political science, veterinary medicine, zoology and entomology.

A charge of £1 a term, or £3 per year, is levied upon all students, under the head of incidental expense. There are dormitories in the university grounds for the use of students at a rent of 6s. per term, and the expense of board, etc., varies from 6s. to 13s. per week. The uniform with which the members of the battalion are required to provide themselves costs about £4 15s. The expenses of a student, excluding clothing (except uniform), and travelling expenses varies from £27 to £75. There is a large amount of work on the university farm which can be performed to advantage by the students, and for which they are paid at current rates for such labour. Some students defray all their expenses in this way.

THE SCHOOL OF ENGINEERING.

The school of engineering consists of those departments represented in the courses leading to the degrees of civil engineer, engineer of mines, and mechanical engineer, and in the short course in mining.

No student is permitted to take less than 15 or more than 18 hours a week of class-room work, except by special permission of the committee of the school in which he is enrolled; and no student will be permitted to take more than the regular work of the class to which he belongs, who has not satisfactorily completed all of his work for the preceding term.

The degree of civil engineer is conferred on those who have completed the course of study in civil engineering; that of engineer of mines on those who have completed a course in mining engineering; that of mechanical engineer on those who have completed the course in mechanical engineering or that in electrical engineering.

Mining Engineering.

The course in mining engineering is arranged for students intending to become mining engineers and surveyors, metallurgical or technical chemists. The curriculum, therefore, while keeping mathematics, drawing, and engineering prominent,

also provides extended work in applied chemistry, chemical analysis, assaying, mineralogy, geology, and surveying, with especial application to mines and underground work, while the treatment of ores, both mechanical in ore-dressing and chemical in metallurgy, forms an important feature :—

First Year.—Mathematics, chemistry, mineralogy, drawing, French or German, English, and military drill.

Second Year.—Mathematics, mechanical laboratory work, metallurgy, French or German, English, military drill, and drawing.

Third Year.—Mechanics, strength of materials, physics, metallurgy, bridge-strains, mine-surveying, assaying, determinative mineralogy, and English.

Fourth Year.—Mining engineering, geology, ore-dressing, metallurgy, electrical engineering, photography, and plans and specifications.

As a requisite for graduation each candidate must present an acceptable thesis embodying the results of a special study. The subject of the study must lie within the field of metallurgy or of mining engineering.

Short Course in Mining.

This course is intended for students lacking time and preparation for the full course, and is principally designed for those who have had some practical experience as miners. The work is more elementary in character than in the long course, and is made to apply especially to coal-mining.

First Year.—Mathematics, physical geography, physics, and military drill.

Second Year.—Mine-surveying, ventilation and haulage, mine operating, mineral chemistry, drawing, mechanical laboratory work, geology, and military drill.

THE CASE SCHOOL OF APPLIED SCIENCE, CLEVELAND, OHIO, UNITED STATES.

The object of this school is to teach mathematics, physics, engineering (mechanical and civil), chemistry, economic geology, mining and metallurgy, natural history, drawing, modern languages, and such other kindred branches of learning as the trustees may deem advisable.

The fee for tuition is £15 per year, and the fees for chemicals and use of instruments and apparatus is £5 per year. Young men who are good mechanics, either carpenters or machinists, and who are dependent upon their own exertions for an education, will be furnished work in the school-shops to pay their tuition in part, if they desire it. The cost of text-books, stationery, etc., will average about £5 per year. Board and rooms can be obtained at from 16s. to 24s. per week. The total expense for tuition, board, room, books, etc., for the school year, may vary from £50 to £70.

Courses of instruction are provided in civil engineering, mechanical engineering, electrical engineering, mining engineering, drawing, physics, chemistry, mineralogy, geology, mathematics, astronomy, architecture, and the English, French, and German languages.

The following regular courses of study have been established; each course requires four years for completion, and for proficiency in any of them the degree of bachelor of science in the course pursued is conferred :—(1) General course; (2) civil engineering; (3) mechanical engineering; (4) mining engineering; (5) electrical engineering; (6) physics; (7) chemistry; and (8) architecture.

The general course is intended for students who do not desire to give as much time to a single topic as is given in the other regular courses. During the last two

years the course is largely optional. During the first year the work is the same for all regular students in the school. At the end of this year the student is expected to select one of the regular courses of study to be pursued during the remaining three years of his course.

The course in mining engineering comprises the studies common to all of the engineering courses, and in addition special instruction in mining surveying, mining machinery, chemistry, mineralogy, geology, and metallurgy as follows:—

First Year.—Algebra, chemistry, chemical laboratory work, descriptive geometry, mechanical drawing, trigonometry, analytical geometry, English literature, rhetoric, and French.

Second Year.—Surveying, calculus, physics, physical laboratory work, mechanism, French, German, chemical analysis, surveying and levelling.

Third Year.—Chemical philosophy, chemical analysis, machine design, mining engineering, mechanical laboratory work, mechanics, materials of engineering, physics, physical laboratory work, mineralogy, German, steam engine, topography, geology, and assaying.

Fourth Year.—Engineering construction, metallurgy, practical metallurgy, and ore treatment.

The course is completed by the preparation of a thesis, for which the greater part of the second semester of the fourth year is assigned.

The degree of bachelor of science will be given to those who complete, in a satisfactory manner, either of the regular courses of study. Previous to the conferring of the degree the candidate must prepare and hand in a satisfactory thesis upon some technical subject, selected by him, with the approval of the professor in charge of the department in which he desires to graduate.

The engineering degrees, viz., civil engineer, mechanical engineer, electrical engineer, and engineer of mines, will be conferred upon graduates in those departments who pursue their technical studies one year more, or have been engaged in professional work in positions of responsibility for three years; in either case a further thesis on an entirely original technical topic, or a detailed account or report of the professional work engaged upon, must be presented for acceptance at least twenty days prior to the date of conferring degrees.

UNIVERSITY OF PENNSYLVANIA, PHILADELPHIA, PENNSYLVANIA, UNITED STATES.

The university comprises the following departments:—The college including arts, science, architecture, natural history, finance and economy, and music, and departments of medicine, law, dentistry, philosophy, veterinary medicine, physical education, and hygiene.

The general course in science covers five years—two years of general literary and scientific study, and three years devoted chiefly to technical training in one of the following courses:—Chemistry, mining and metallurgy, civil engineering, and mechanical and electrical engineering.

The work of the first and second years in science includes English, history, mathematics, drawing, chemistry, physics, hygiene, and one modern language (German or French).

In the years devoted to technical instruction are included courses in English, the modern languages, history, philosophy, and political economy, with the necessary instruction in pure and applied mathematics and the scientific branches allied to the principal subject of the course.

Students of regular standing receive at the end of the fourth year the general degree of bachelor of science, and at the end of the fifth year the degree of master of science. The technical degree appropriate to the course pursued may be conferred upon masters of science of two years' standing who have made satisfactory progress in their professions and have presented an acceptable thesis.

TOWNE SCIENTIFIC SCHOOL.

The courses in this school are divided into two groups. In the one are included the courses which are regarded as the continuation of the general course in science; in the other the courses of technical instruction of four years. The technical divisions of the general course in science cover three years.

Good board can be had near the university at from 20s. to 30s. a week. The expenses, including board, tuition, and text-books, will vary from £55 to £95 per annum.

The courses are :—(1) Pure and applied chemistry; (2) metallurgy and mining; (3) civil engineering; and (4) mechanical engineering.

Third Year.—English literature, rhetoric and declamation, German or French, differential and integral calculus, heat and light, electricity and magnetism, mining engineering, mines and mining machinery, prospecting and developing mineral deposits, crystallography, lithology, qualitative chemical analysis, civil engineering, applied mechanics, map projection, graphics, and surveying.

Fourth Year.—English, rhetoric and declamation, economics and social science, experimental physics, physical laboratory work, theory of metallurgical processes, assaying, construction of parts of mines and of mining machinery from notes and sketches, machinery employed in haulage, hoisting, and pumping, mineralogy, gravimetric and volumetric analysis.

Fifth Year.—Metallurgy, mining engineering, geology, and analytical chemistry.

Degrees.

Technical courses of four years lead to the degrees of bachelor of science in mechanical engineering, in electrical engineering, in civil engineering, in chemistry, and in architecture, respectively.

Bachelors of science in mechanical and electrical engineering, civil engineering, architecture, or chemistry, of three years' standing, who have shown marked progress in their professions and have submitted a satisfactory thesis, may receive the degree of master of science, together with the technical degrees appropriate to the course pursued.

The degree of master of arts or of science is conferred upon bachelors of arts or science respectively, on examination after one year of resident study.

THE LEHIGH UNIVERSITY, SOUTH BETHLEHEM, PENNSYLVANIA UNITED STATES.

The necessary expenses for the collegiate year (clothing and travelling not included) vary from £70 to £100.

THE SCHOOL OF TECHNOLOGY.

This school includes seven distinct courses: civil engineering, mechanical engineering, mining, metallurgy, electrical engineering, chemistry, and architecture.

The courses in mining and metallurgy aim at fitting the student for practical work in either of the branches of mining, metallurgy, metallurgical chemistry or geology.

At the end of the first year an opportunity is given the student to select one of two courses leading to the various degrees. These allow a full course in either mining or metallurgy to be acquired in four years, and afford to the student whose time is limited and who desires to practice one of the above branches the means for rapid work. The graduate in either course can obtain the engineer's degree (E.M.) by one year of post-graduate work. For graduates of this university in the course of civil engineering, a one year course has been arranged, leading to the degree of bachelor of science in metallurgy (B.Sc.).

The programme of subjects and studies for the degree of engineer of mines comprise one modern language (French or German), drawing and construction, chemistry, mineralogy, geology, astronomy, applied mechanics, surveying, metallurgy, and mining.

The course of instruction is as follows:—

First Year.—Mathematics, surveying, English, rhetoric, chemistry, French or German, drawing, physiology and health, and gymnasium.

The Course in Metallurgy.

Second Year.—Mathematics, analytical geometry, differential and integral calculus, mechanics, heat, magnetism, electricity, French or German, drawings of metallurgical plant, surveying, chemistry, chemical laboratory work, stoichiometry, English, essays and declamation, and gymnasium.

Third Year.—Mathematics, calculus, analytical mechanics, strength of material, crystallography, assaying, chemical philosophy, French or German, metallurgy, mineralogy, blowpipe analysis, chemistry, quantitative analysis, steam engine, essays and orations, literature and history, and gymnasium.

Fourth Year.—Metallurgy, blowpipe analysis, lithology, mechanics of machinery, quantitative analysis, chemistry, graphical statics, projects in metallurgy, mining, geology, hydraulics, hydrostatics, designing of furnaces and metallurgical plant, American and English literature, Christian evidences, preparation of thesis, and gymnasium.

Fifth Year.—Mining, geology, drawing of mining plant, surveying, astronomy, geological surveying, and preparation of thesis.

The Course in Mining.

Second Year.—Mathematics, analytical geometry, differential and integral calculus, mechanics, heat, magnetism, electricity, French or German, crystallography, surveying, levelling, chemistry and laboratory practice, mineralogy, English, essays, and gymnasium.

Third Year.—Mathematics, calculus, analytical mechanics, strength of materials, geology, lithology, surveying, levelling, blowpipe analysis, steam engine, geological surveying, French or German, literature and history, essays and orations, and gymnasium.

Fourth Year.—Mining, mechanics of machinery, astronomy, surveying, assaying, drawing of mining plant, projects in geology and mining, hydraulics, hydrostatics, American and English literature, Christian evidences, preparation of thesis, and gymnasium.

Fifth Year.—Metallurgy, blowpipe analysis, quantitative analysis, chemical laboratory work, chemical philosophy, drawing, designing furnaces and other metallurgical plant, graphical statics, stoichiometry, projects in metallurgy, astronomy, and preparation of thesis.

Every student will be required to present a thesis upon some topic connected with his special course as a necessary portion of the exercises for his final examination for a diploma. These theses shall be accompanied by drawings and diagrams, when the subjects need such illustration.

Degrees.

On account of the great number and scope of the studies necessary to the attainment of the degree of engineer of mines (E.M.), which includes that of metallurgist, five years are required. At the end of the fourth year the student will have completed a course similar to that leading to the scientific degree in other institutions, and will receive the degree of bachelor of science (B.Sc.).

The faculty will recommend for the degree of master of science any candidate, otherwise properly qualified, who, after taking at this university the degree of bachelor of science, or any degree in the School of Technology, shall pursue, for at least one year at this university, or two years elsewhere, a course of study prescribed by the faculty in at least two departments, pass a thorough examination in the same, and present a satisfactory thesis.

The faculty will recommend for the degree of doctor of philosophy any candidate, otherwise properly qualified, who, after taking at this university the degree of master of arts or master of science, shall pursue, for at least one year at this university, or two years elsewhere, a course of advanced study prescribed by the faculty, in at least two departments, pass a thorough examination in the presence of the faculty in the same, and present a satisfactory thesis giving evidence of original investigation. The candidate must have a good knowledge of Latin, and either French or German.

LAFAYETTE COLLEGE, EASTON, PENNSYLVANIA, UNITED STATES.

The aim of Lafayette College is distinctly religious. Under the general direction of the Synod of Pennsylvania of the Presbyterian Church its instruction is in full sympathy with the doctrines of that body. At the same time religious instruction is carried on with a view to a broad and general direction along the lines of general acceptance among evangelical Christians, the points of agreement, rather than those of disagreement, being dwelt upon. Students are expected to attend one of the Presbyterian churches, or a church of the denomination to which they or their parents belong.

The annual college charges are, for those who pay tuition in full, about £23 for technical studies. With economy, the total annual expenses—exclusive of tuition, clothing, and travelling expenses—need not exceed £50.

Biblical instruction is given in every class of all departments in each week. In the first year a general view of the contents of the Bible and of each book is given, with special attention to chronology, history, and geography. In the second year the Acts of the Apostles is the subject of instruction. In the third year the Epistle to the Romans is studied: the students in the scientific courses read it in German. In the fourth year a course in Christian ethics is given and instruction in Christian evidences. Instruction in the history of the English Bible, its translations and its translators, its merits and its influence, is given from time to time. It is intended that the Bible shall be a central object of study throughout the course.

The lectures on health during the first year include the general principles of physiology and anatomy, and special consideration is also given to the bearing of the facts and principles upon natural theology.

Engineer of Mines.

There are three courses in engineering—those of civil, mining, and electrical engineering. The instruction in all the engineering courses is substantially the same during the first two years of the course, except that the electrical engineers substitute the study of physics and practical work in the physical laboratory for a part of the surveying, field, and office-work of the other courses.

The course leading to the degree of engineer of mines is intended to provide in a thorough manner a good foundation for professional work, by a careful study of the facts and principles involved in the numerous problems which are encountered by the mining engineer in the practice of his profession.

First Year.—Mathematics, chemistry, drawing, physiology, French and German, surveying, plane and spherical trigonometry, and mensuration.

Second Year.—Mathematics (analytical geometry, differential calculus, integral calculus), French and German, English, drawing, surveying, mineralogy, practice with blow-pipe, and botany.

Third Year.—Mechanics, surveying, mining, qualitative analysis, heat, light, electricity, descriptive geometry, drawing, quantitative analysis, assaying, optics, acoustics, resistance of materials, elements of machinery, building construction, geology, and New Testament epistles in German.

Fourth Year.—Steam engine, mine-surveying, map of mine-survey, machine drawing and designing, graphical statics, metallurgy, mining, quarrying, political economy, history, quantitative analysis, and graduation thesis.

Degrees.

The degree of civil engineer is conferred on graduates of the civil engineering course; engineer of mines on those of the mining engineering course; and electrical engineer on those of the electrical engineering course.

The degree of master of science may be conferred three years after graduation on any graduate of the scientific department who has passed his graduate period in collegiate or professional study and practice, or who shall submit to the faculty a satisfactory literary, philosophical, or scientific paper. The same degree may be conferred two years after graduation on any graduate of the scientific department who shall have devoted at least one year exclusively to advanced study in the college under the direction of the faculty and passed examinations in the studies pursued.

The degree of doctor of philosophy may be conferred on any graduate of this college who shall have taken a prescribed course of special reading for three years after graduation, passed examinations in approved courses of study, and presented a thesis showing evidence of original research. The same degree may be conferred two years after graduation on any college graduate who, during two years of continuous residence at the college, shall have devoted himself exclusively to advanced studies under the direction of the faculty, passed examinations in them, and presented a satisfactory thesis on one of the studies pursued.

INDEX TO VOL. V.

EXPLANATIONS.

The — at the beginning of a line denotes the repetition of a word; and in the case of Names, it includes both the Christian Name and the Surname.

Discussions are printed in *italics*.

The following contractions are used :—

C.—Chesterfield and Midland Counties Institution of Engineers.

M.—Midland Institute of Mining, Civil, and Mechanical Engineers.

N.E.—North of England Institute of Mining and Mechanical Engineers.

N.S.—North Staffordshire Institute of Mining and Mechanical Engineers.

S.S.—South Staffordshire and East Worcestershire Institute of Mining Engineers.

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